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PUMPS Troubleshooting & Sizing

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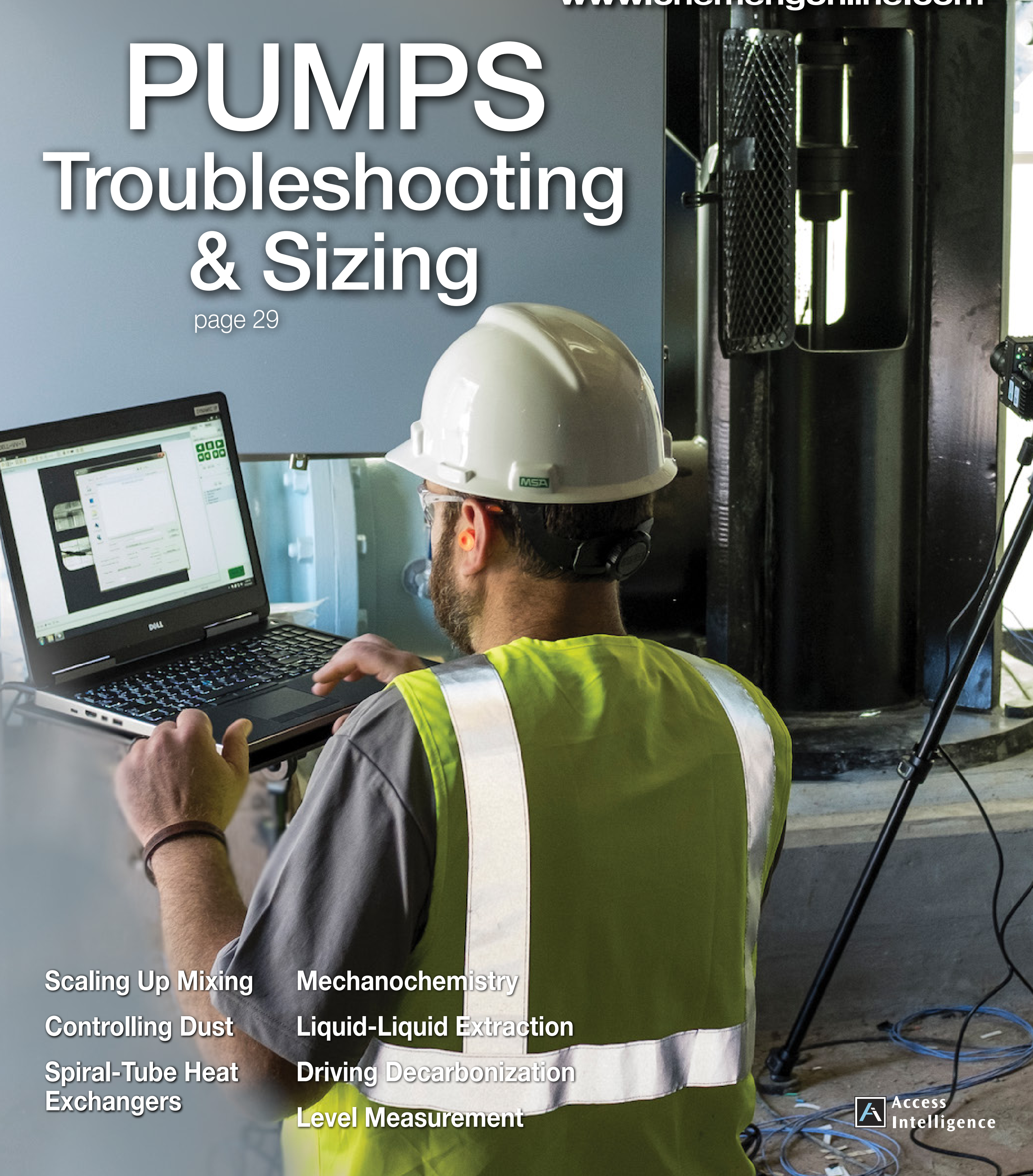

Scaling Up Mixing

Controlling Dust

Spiral-Tube Heat Exchangers

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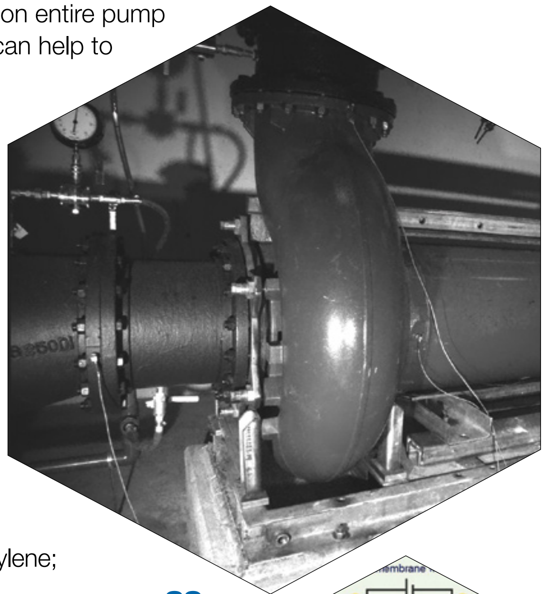
In the News



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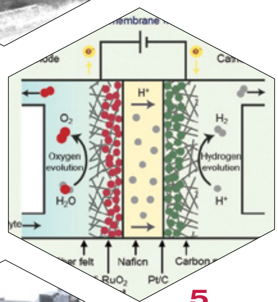

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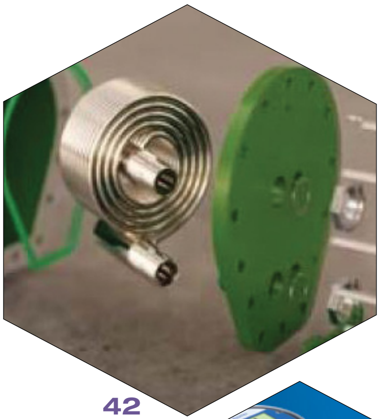

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Cover design: Tara Bekman

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Editor's Page

120 years and going strong

This year marks *Chemical Engineering*'s 120th anniversary. At this extraordinary milestone, I paused to look into the history of the publication and its evolution to where we are now. The magazine evolved, changing its name to reflect changes and combinations of disciplines as industries grew into what we now collectively call the chemical process industries (CPI). Our publication has also grown to be much more than a magazine, into a brand that includes all the modern modes of sharing information online, in-person and still also in print. The one thing that has remained the same over the years is the publication's dedication to serve our CPI readers.

Our history

In September of 1902, the first issue of *Electrochemical Industry* was published to serve those applying the principles of electrochemistry in industry. Excerpts from that first issue indicate that growth in the electrochemical industry was largely aided by the growing availability of electric power, particularly from hydroelectric power such as at Niagara Falls. An article in that issue by professor C.F. Burgess states that "Chemical manufacturing was a number of years ago considered best developed when the processes were so simple that no power was necessary to assist in the chemical reactions, but this condition has changed and the chemical industries are now pre-eminently power-using industries." In 1905, the publication's coverage had outgrown its initial title, and the name was changed to *Electrochemical and Metallurgical Industry*.

In January 1910, the name changed again to *Metallurgical and Chemical Engineering*. One interesting report from that issue described "A continuous distillation column of unique design recently built by the firm of Walter E. Lummus. . . known as a three-product distilling machine." The June 1910 issue described a new process for ammonia that had just been heard of from Europe to synthesize ammonia from nitrogen and hydrogen. While the prevailing thought was that the gases would be too slow to react, professor Fritz Haber showed that the reaction could occur under high pressures with a catalytic agent.

The July 1918 issue announced another name change to *Chemical and Metallurgical Engineering*. Placing "chemical" first may be best explained by an excerpt from page 1 of that 1918 issue: "It must now be quite evident to any observer of current industrial development what we foresaw several years ago, namely, that chemical engineering is playing the dominant role of the day. Our country stands on the threshold of a marvelous development which has its basis in applied chemistry. There is scarcely an industry of any magnitude or importance that is without its chemical phase, and we are but beginning to appreciate the value of chemical control."

In August 1946, the magazine's name was changed to its current title *Chemical Engineering*.

History is both interesting and valuable. The history of technological developments and the people behind them is rich with lessons to be learned, some of which find new applications today. With this in mind, we plan to periodically look at some aspect of our industries' history in Chem Chronicles — a column we introduced earlier this year, and can be found on page 26 of this issue. And as always, we strive to keep our readers up-to-date with new technologies, business news and practical information — "Essentials for the CPI Professional." ■

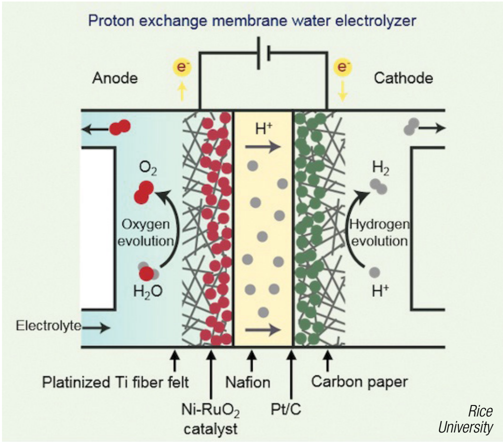
Dorothy Lozowski, Editorial Director

Edited by:
Gerald Ondrey

Iridium-free electrolysis demonstrated for stable hydrogen production

The necessity for precious metals, such as iridium, in water-splitting catalysts is a major challenge in the feasibility of large-scale production of hydrogen using electrolysis. Now, a team of researchers from Rice University (Houston; www.rice.edu) has developed a mechanism for replacing iridium with ruthenium, which is significantly more abundant and less expensive, into an electrolysis anode catalyst.

To make the catalyst, a three-step process was developed to incorporate nickel into a RuO_2 lattice. "First, a wet impregnation of metal precursors was adopted on the carbon black support, which was followed by H_2/Ar annealing reduction to obtain Ru_3Ni nanoparticles supported on carbon black (Ru_3Ni/C). Secondly, the obtained Ru_3Ni/C complex was annealed in air to convert the nanoparticles to Ru_3NiOx and to remove the carbon supports. Finally, the Ru_3NiOx underwent an acid-leaching process to remove unstable Ni species and get the final catalyst, Ni-RuO_2," explains Haotian Wang, assistant professor of chemical and biomolecular engineering at Rice. This method resulted in a stable anode catalyst, which the team says has been employed in an electrolysis cell to produce hydrogen for thousands of hours under ambient conditions.



Rice University

According to Wang, the team believes their catalyst could be integrated into different types of polymer electrolyte membrane (PEM) electrolyzer.

Thus far, the team has loaded the catalyst on a 1-cm^2 platinized titanium fiber-felt electrode at a rate of around 3.1 mg/cm^2, and for each batch of synthesis, around 100 mg of Ni-RuO_2 can be produced. "We plan to scale up the synthesis of our Ni-RuO_2 catalysts by using larger reaction vessels and tube furnaces," adds Wang. The team is also examining ways to improve current density in the cell.

Recycling halogens electrochemically

Next April, a six-year, €4-million project will begin that aims to develop an electrochemical process to recover halogens (chlorine, bromine and fluorine) from waste products. Funded as part of the CZS Breakthrough program of the Carl Zeiss Foundation (CZS; Heidenheim an der Brenz, Germany; www.carl-zeiss-stiftung.de), the Halocycles project has three major objectives: increasing the recovery of fossil raw materials, avoiding CO_2 emissions and stabilizing the energy-supply network. It will be carried out by partners Johannes Gutenberg University Mainz (JGU; www.uni-mainz.de) and the Technical University of Kaiserslautern (both Germany; www.uni-kl.de). Additional participants in the project are the Max-Planck Institute for Polymer Research (Mainz) and the Leibniz-Institute für Verbundwerkstoffe GmbH (IVW; Kaiserslautern).

There are many common products made from halogen compounds, such as polyvinylchloride (PVC), polytetrafluoroethylene (PTFE or Teflon) and flame retardants. Their unique properties make them irreplacable in many applications, and these properties also make them difficult to recycle. Today, the only way to recover the halogens, which are becoming more expensive, is to incinerate the halocarbons, and then recover the halogens via fluegas-scrubbing techniques. However, burning these compounds not only requires additional fuels for achieving the required temperatures to breakdown the compounds, but also destroys the carbon backbone, which is then released as CO_2.

"In our new Halocycles project, we are approaching this issue from a completely different direction," says professor Siegfried Waldvogel of JGU's Department of Chemistry, who is the project's spokesperson and an authority on electrosynthesis (see "Electrochemistry Spreads its Wings," *Chem. Eng.*, September 2021, pp. 12–16). "Our idea is to use an electrochemical technique to recover the halogens without burning the carbon structures. Thus, we also avoid the formation of dioxins."

The partners will also consider utilizing and exploiting the results of the research in a spin-off, which may be established later on.

Li EXTRACTION

A new technology is going to be introduced at the Schlumberger NeoLith Energy direct lithium-extraction (DLE) project in Clayton Valley, Nev. Developed by Gradiant Ventures (Boston, Mass.; www.gradiant.com), the technology enables high levels of lithium concentration (while simultaneously generating fresh water) using a fraction of the time required by conventional thermal concentration methods, explains Gradiant's chief operating officer, Prakash Govindan. "This is the first industrial-scale deployment of the technology for battery-grade lithium production," he adds, noting that the technology has previously been demonstrated in production processes for gold, nickel and graphite.

Based on research work from the Massachusetts Institute of Technology (MIT; Cambridge, Mass.; www.mit.edu), Gradiant's technology is also set for deployment for ultrapure water treatment at a semiconductor manufacturer in Singapore starting up in early 2023.

VEGETABLE OIL

Scientists from Nanyang Technological University, Singapore (NTU Singapore; www.ntu.edu.sg) have genetically modified a plant protein that is responsible for oil accumulation in plant seeds and edible nuts. Demonstrating their patent-pending method, the model plant *Arabidopsis* accumulated 15 to 18% more oil in its seeds when it was grown with the modified protein under laboratory conditions.

The secret to helping plants store more oil in

(Continues on p. 6)

their seeds is one of their proteins called WRINKLED1 (WRI1). For over two decades, scientists have known that WRI1 plays an important role in controlling plant-seed oil production. Now for the first time, a high-resolution structure of WRI1 has been imaged and reported by the NTU team, jointly led by associate professor Gao Yonggui and assistant professor Ma Wei from the School of Biological Sciences.

In a recent issue of *Science Advances*, the team detailed the molecular structure of WRI1 and how it binds to plant DNA, which signals to the plant how much oil to accumulate in its seeds. Based on the understanding that the atomic structure of the WRI1-DNA complex revealed, the team modified WRI1 to enhance its affinity for DNA in a bid to improve oil yield.

The team has filed a patent for their method of gene modification through NTUitive, the University's innovation and enterprise office, and is looking for industry partners to commercialize their invention.

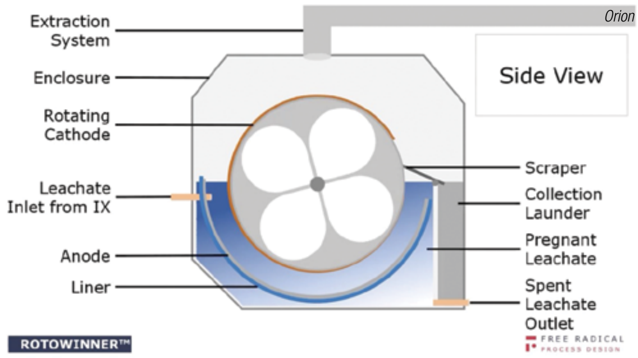
PEM CATALYST

Iridium is presently essential to electrolyzers working with proton-exchange membrane (PEM) technology, but the Ir is both scarce and expensive, so efforts are underway to reduce the amount of this precious element needed (see also story on p. 5, and *Chem. Eng.* November 2022, p. 7).

TNO (The Hague, the Netherlands; www.tno.nl) researchers of the Faraday Lab (Petten), in collaboration with colleagues from the Holst Center (Eindhoven, both the Netherlands) have developed a method that will require 200 times less iridium, while performing at 25 to 46% that of existing electrolyzers. The

(Continues on p. 8)

Making more from mining water with electrowinning



A new electrowinning process is being field-trialed at the Prieska copper-zinc mine operated by Orion Minerals Ltd. (Melbourne, Australia; www.orionminerals.com.au) in South Africa, which will enable the production of valuable products, including calcium, magnesium, iron and others, from contaminated mine water, while also potentially replacing expensive reverse-osmosis water-treatment systems.

At the heart of the process is the proprietary Rotowinner technology developed by Free Radical Process Design (FRPD; www.frpd.biz; Pretoria, South Africa), which is a fully enclosed, continuous electrowinning technology to recover selected components from mineralized leachate using a rotating cathode that is submerged in pregnant leachate. A built-in scraping process removes precipitated minerals from the cathode and collects them, while the spent leachate is recycled. Because cathode-stripping is integrated and continuous, the Rotowinner process requires fewer manual steps and less energy to operate than traditional electrowinning systems, and demonstrates a higher throughput (as much as 15%, says FRPD). Improved laminar-flow dynamics within the system result in better mass transfer and current density. Furthermore, says the company, electron-transfer efficiency is boosted because the system is designed with smaller inter-electrode distances to minimize resistance. The Prieska field trials, which are expected to occur for about six months, are employing a mobile demonstration plant operating on a continuous basis, following successful laboratory tests.

Orion estimates that the Prieska mine contains around 9 million ft^3 of water requiring treatment due to its solids content, and the company is currently setting up for a 3.5-yr dewatering period. If the field trials are successful, the companies intend to implement a production-scale Rotowinner system to treat the water, extracting minerals and nutrients for local agricultural and industry use, as well as producing a treated water stream for local irrigation.

Using 'ecoke' to reduce CO_2 emissions from steelmaking

Liberty Steel UK (LSUK; London; www.libertysteelgroup.com) has completed trials of ecoke — a sustainable new raw material that can replace anthracite, the main source of charge carbon used in the electric-arc furnace (EAF) of steelmaking, and reduce steel's carbon footprint by as much as 30%. The ecoke initiative is part of the company's drive to lead transformation of steel manufacturing through its "Greensteel" strategy. Production at LSUK's EAF in Rotherham generates just 10% of the direct emissions compared with traditional coal-based blast furnaces, which produce the vast majority of the U.K.'s steel output.

LSUK's steelmaking team at Aldwarke Cast Products (ACP) in Rotherham performed a review of the processes to identify opportunities to reduce its CO_2 emissions. The team identified anthracite as the main source of charge carbon in EAF production — accounting for between 86 and 97% of the carbon charge. A steering team was formed in Rotherham to replace anthracite with an environmentally sustainable alternative. The group considered all available options and finally identified CPL Industries (Sheffield, U.K.; www.ecoke.biz) as local supplier of a biofuel called ecoke.

Ecoke is made by combining fossil-fuel and biomass fines with a binder, which is then formed into briquettes that are heat-cured, water-quenched and dried. The briquettes contain a minimum of 30% secondary biomass, giving a CO_2 reduction of 30%. The briquettes are delivered to the site in similar packaging to the anthracite and ecoke is charged into the EAF in the same manner as the anthracite via the scrap basket.

In addition to the environmental benefits, the reduction in carbon credits would provide a "substantial" cost saving for the company. "The major reductions in CO_2 emissions ecoke enables, without any downside to the production process, can help to further decarbonize our production and the wider steel industry," says Scott Jackson, plant manager at ACP of Liberty Speciality Steels.

method is based on spatial atomic layer deposition (sALD) technology, which applies extremely thin layers of functional materials to large surface areas. TNO initially developed this technology for the next generation of television, tablet and smartphone displays. Now, the research team has also made the technology applicable to electrolyzers, and a patent application has been filed.

TNO has spent the last two years experimenting with the sALD technology. Researchers applied an ultrathin layer of iridium as a catalyst material on a porous transport layer of titanium, instead of on a membrane, as is presently customary. The functioning and stability of the new method has been proven after different laboratory tests. Little to no degradation occurred after initial stress testing.

Together with a group of leading industrial partners and within the Voltachem program, TNO is working on moving this promising technology from the laboratory to practice. For this, the method needs to be scaled up to pilot scale to demonstrate its functioning under real-life conditions.

CHEMICALS FROM AIR

It is possible to capture CO_2 from the surrounding atmosphere and repurpose it into useful chemicals usually made from fossil fuels, according to a study from the University of Surrey (Guilford, U.K.; www.surrey.ac.uk) that was recently published in *Nanoscale*. The technology uses patent-pending switchable dual-function materials (DFMs), which capture CO_2 on their surface and catalyze the conversion of captured CO_2 directly into chemicals. The "switchable" nature of the DFMs comes from their ability to produce multiple chemicals, depending on the operating conditions or the composition of the added reactant. This makes the technology responsive to variations in the demand for chemicals, as well as availability of renewable hydrogen as a reactant.

The DFMs are composed of Ni-Ru bimetallic catalyst with Na_2O, K_2O or CaO adsorbent supported on CeO_2-Al_2O_3, and can be designed to flexibly produce chemicals from dilute sources of CO_2 through the combination of CO_2 adsorption and subsequent chemical reactions (methanation, reverse water-

(Continues on p. 10)

Supercritical extraction drives 'molecular washing machine' for plastic waste

A new recycling process has been developed for scrap polypropylene (PP), a waste stream that is currently underserved by many plastics-recycling facilities. The process, developed by PureCycle (Orlando, Fla.; www.purecycle.com), aims to "wash the plastic molecules" using a series of purification processes to eliminate contaminants, odors and colors, yielding a high-purity stream of PP, unlike in mechanical recycling where the contaminants are still included in the final product. And unlike depolymerization, PureCycle's technology is a physical separation process, with no reactive chemistry — just phase-change and physical-property separations, explains Dustin Olson, CEO of PureCycle.

"We effectively manage the solubility of PP in a way that allows us to remove other contaminants that are not soluble. We have a supercritical extraction step where we remove all the organics, and then we have a phase-change management scheme where we are able to separate all of the non-soluble components, leaving PP in the soluble phase," adds Olson.

The key to PureCycle's technology is the extraction step, which uses a recyclable, widely available solvent, and takes advantage of supercritical phase conditions. "Taking what we've learned with supercritical CO_2 extraction, at the temperature and pressure that puts the process into the supercritical regime, you see hyper-extraction behavior, which gives us the capability to really 'wash' the molecules in an effective way," says Olson.

PureCycle has tested its process in a pilot plant using a range of PP grades, including homopolymer, copolymer and impact copolymer, and has shown that the process successfully removes the range of contaminants present, from other plastics, such as polyethylene, to talc and rubber. Another benefit of the process, says Olson, is that the contaminant-containing streams are also potentially saleable coproducts, with one coproduct resembling pyrolysis oil and the other coproduct resembling mechanically recycled polyethylene.

The company is preparing to start up its first commercial-scale recycling plant in Ironton, Ohio in early 2023, and plans are underway for additional commercial plants in Europe and South Korea to come onstream in the next few years.

New smelting furnace enables the use of lower-grade ore in DRI ironmaking

In late October, Metso Outotec Corp. (Helsinki, Finland; www.mogroup.com) introduced the DRI (direct reduced iron) Smelting Furnace to substitute blast furnaces used in iron- and steelmaking. The furnace was developed to tolerate high-slag volumes, which are problematic for a conventional electric-arc furnace (EAF). When a conventional EAF is used to melt hydrogen-based DRI, gangue content of iron ore needs to be low, otherwise, the slag generation and iron losses will increase drastically in the EAF process, according to the company. Only less than 3% of the world's iron ore fulfills the requirement, the company adds.

"Combined with a direct reduction plant, the DRI Smelting Furnace will substitute blast furnaces in the production of hot metal. This is an optimal solution for primary steel producers aiming for a significant reduction in their CO_2 emissions with minimal changes to the rest of the steel plant. The furnace can be integrated with Metso Outotec's H_2-based Circored process [*Chem. Eng.*, June 2022, p. 5] or other direct-reduction processes," says Kimmo Vallo, product manager, DRI Smelting Furnace at Metso Outotec. Replacing blast furnaces with direct-reduction plants and DRI Smelting Furnace technology using "green" H_2 and energy can avoid 80–90% of CO_2 emissions from steelmaking, the company says.

DRI Smelting Furnace technology is based on proven Metso Outotec equipment — electrode equipment; furnace structure, based on the company's Flash Smelter; Venturi scrubber; cooling elements; and advanced automation tools and digital twins. The Furnace and related products are complete and ready for implementation. User-specific pilot-scale testing will be conducted in the Metso Outotec research facilities to demonstrate large-scale DRI smelting. The new 6-in.-line DRI Smelting Furnace offers high productivity with capacities above 1.2 million ton/yr.

gas shift or dry reforming of methane), according to the publication. The DFMs were shown to reversibly adsorb CO_2 at temperatures berween 350 and 650°C, and can be regenerated by purging with an inert gas. The proof-of-concept is said to be a milestone in the development of carbon-negative technologies.

SMART SENSOR

Researchers at the King Abdullah University of Science and Technology (KAUST; Thuwal, Saudi Arabia; www.kaust.edu.sa) have developed a chemical sensor that, combined with artificial intelligence (AI) and machine learning (ML), can be trained to detect gases in air with high selectivity and sensitivity. Instead of using exotic materials or special coatings, the sensor uses a heated strip of silicon, called a microbeam resonator. When bent near the buckling point and clamped at both ends, this microbeam resonates at a frequency that is very sensitive to temperature. The heated microbeam is thus responsive to gases with different thermal conductivities. Shifts in resonance frequencies are detected using a microsystem vibrometer analyzer. AI is used to analyze data to identify characteristic frequency changes of various gases, and data processing and ML algorithms are used to generate markers for each gas. Once trained, the sensor can identify specific gases with 100% accuracy.

SILOXANE PRODUCTION

In late October, Wacker Chemie AG (Munich, Germany; www.wacker.com) bestowed its 2022 Net Zero Award to a project team comprising Martin Steuer from the methyl chloride synthesis/hydrolysis plant at the Nünchritz site, Sebastian Kröner from Process Development at Central Engineering in Burghausen and Konrad Mautner from Wacker Silicones Technology Management. The internal prize was established last year to honor projects implementing Wacker Group's sustainability goals. The company aims to reduce its absolute greenhouse-gas emissions by 50% by 2030 and become climate-neutral by 2045.

The winners developed a process with which a high percentage of organosilicon byproducts from hydrolysis of chlorosilanes is returned into the integrated production system in a targeted manner. The hydrolysis of chlorosilane is part of the upstream process, which starts out from metallurgical silicon to produce the intermediates chlorosilane and siloxane and ultimately to obtain the downstream product silicone.

The award-winning process is already in use on an industrial scale at the Nünchritz site and is to be implemented at the Burghausen site in the coming years. ❐

Quantitative microbial monitoring for corrosion-relevant organisms

LuminUltra Technologies Ltd. (Fredericton, N.B., Canada; www.luminultra.com) recently launched a suite of DNA-based monitoring tools specifically designed to address organisms linked to microbiologically influenced corrosion (MIC). The collection enables industrial users to collect, prepare and test samples for a range of MIC targets, yielding quantifiable and actionable results, comments Jordan Schmidt, director of product applications at LuminUltra.

MIC, referring to corrosion that is induced or accelerated by the activity of microorganisms, has been a costly and persistent challenge for metal surfaces in the chemical processing, oil-and-gas and power generation sectors, among others. The test kits monitor for the presence and amount of specific microbes by purifying and amplifying DNA segments unique to those organisms using quantitative polymerase chain reaction (qPCR) methods.

LuminUltra's molecular biology tools yield results in as little as two hours, compared to the weeks required by traditional testing methods, and are designed for testing at user facilities, the company says.

The LuminUltra qPCR assay kits target a number of MIC microbes, including sulfate-reducing prokaryotes, iron-reducing bacteria, total methanogens, corrosive methanogens (micH), sulfur-oxidizing bacteria and more. The company's product suite also includes auto-extraction equipment and sample preservation and purification kits.

"The ability to analyze microbial communities and diagnose corrosion on asset surfaces is a valuable capability for facilities across the chemical process industries," says Schmidt, "and the initial feedback resulting from this new MIC-specific offering has been tremendous."

A direct, biocatalytic route from CO_2 to ethylene

LanzaTech Inc. (Chicago, Ill.; www.lanzatech.com) has developed a genetically engineered bacterium capable of converting carbon dioxide directly to ethylene, the most widely used chemical building block globally. The company has incorporated the engineered biocatalyst into a continuous process in a benchtop bioreactor.

The development could have broad implications for global carbon reduction and CO_2 utilization. "This process could allow large reductions in the need for ethylene derived from petroleum," says Michael Köpke, vice president for synthetic biology at LanzaTech. "We envision a cost-efficient process for ethylene production that is carbon-negative and is also able to take advantage of existing downstream infrastructure for ethylene derivatives."

The CO_2-to-ethylene direct route is built on LanzaTech's existing gas-fermentation platform, which has previously demonstrated the production of ethanol from CO_2. In that case, the ethanol can be catalytically dehydrated to ethylene in a separate process step. "The ability to convert CO_2 directly to ethylene in a 'gas-to-gas' process improves overall costs and carbon efficiency of the project," Köpke notes.

Using LanzaTech's genetic toolbox for gas-fermentation organisms, the company engineered a proprietary bacterial strain capable of expressing a set of genes that encodes an enzyme cascade for the transformation of CO_2 to ethylene. The process does require a source of hydrogen, Köpke says, but the microbes are tolerant of a host of contaminants, so the CO_2 purity of the feed gas can vary quite widely.

"Synthetic biology tools were critical for reprogramming the organisms to produce the desired products, as well as for controlling genetic expression and screening microbial strains," Köpke states.

LanzaTech is now working to optimize the CO_2-to-ethylene direct process in preparation for moving the process to pilot scale.

LanzaTech is already a leader in the scale-up and commercialization of gas-conversion biotechnology. It was the winner of the 2019 Kirkpatrick Chemical Engineering Achievement Award for its gas-fermentation technology (see *Chem. Eng.* January 2020, pp. 23–26). ■

LINEUP

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Plant Watch

Solvay resumes soda-ash expansion in Wyoming

November 11, 2022 — Solvay S.A. (Brussels, Belgium; www.solvay.com) plans to resume the construction of its soda-ash capacity expansion in Green River, Wyo. The investment totals around $200 million, and the expansion will raise the site's capacity to 600,000 metric tons per year (m.t./yr). Production is expected to start at the end of 2024.

Albemarle investing up to $540 million to expand bromine facilities in Arkansas

November 11, 2022 — Albemarle Corp. (Charlotte, N.C.; www.albemarle.com) announced investments of up to $540 million to expand and modernize two bromine facilities in Magnolia, Ark. The planned investments have begun and will continue through 2027. The sites produce bromine and derivative products used in fire safety, chemical synthesis, drilling and completion fluids, water purification and various other industrial applications.

Stora Enso launches bioplastics pilot plant in Belgium

November 3, 2022 — Stora Enso Oyj (Helsinki, Finland; www.storaenso.com) launched a new bioplastics pilot plant in the Flanders region in Belgium, which will produce furandicarboxylic acid (FDCA), a major building block of the bioplastic polyethylene furanoate (PEF). The pilot facility will initially use industrially available fructose to produce high-value chemicals and materials for application testing. In the future, the intention is to run the process on sugars extracted from wood and other non-food-based biomass.

Röhm and OQ Chemicals break ground on new world-scale MMA plant in Texas

October 28, 2022 — Röhm (Darmstadt, Germany; www.roehm.com) and OQ Chemicals GmbH (Monheim am Rhein, Germany; chemicals.oq.com) officially broke ground on a new world-scale methyl methacrylate (MMA) plant. The new facility will be constructed by Röhm at OQ Chemicals' production site at Bay City, Tex. Here, OQ Chemicals will supply the new plant with key raw materials and provide site services and utilities to Röhm. Once completed in early 2024, the new plant will produce 250,000 m.t./yr of MMA

ICL Group to build LFP cathode-material manufacturing plant in St. Louis

October 24, 2022 — ICL Group (Tel Aviv, Israel; www.icl-group.com) plans to build a $400-million lithium iron phosphate (LFP) cathode active material (CAM) manufacturing plant in St. Louis, Mo. This is expected to be the first large-scale LFP material manufacturing plant in the U.S. The plant is expected to be operational by 2024.

Borealis announces plans for first-of-its-kind recycling plant in Austria

October 24, 2022 — Borealis AG (Vienna, Austria; www.borealisgroup.com) is designing a first-of-its-kind commercial-scale advanced mechanical-recycling plant to be located in Schwechat, Austria. The new plant will have the capacity to produce over 60,000 m.t./yr of recycled polyolefin compounds. The first volumes of recycled polyolefin products are expected in 2025.

Mergers & Acquisitions

Bayer acquires German crop-protection startup Targenomix

November 11, 2022 — Bayer AG (Leverkusen, Germany; www.bayer.com) announced the acquisition of German biotechnology startup Targenomix. Targenomix, a spinoff from the Max Planck Institute for Molecular Plant Physiology, uses novel systems biology and computational life-science tools to identify new modes of action for crop protection compounds.

Ascend Performance Materials acquires majority stake in recycling firm

November 8, 2022 — Ascend Performance Materials (Houston; www.ascendmaterials.com) has purchased a majority stake in California-based Circular Polymers, a recycler of post-consumer, high-performance polymers including polyamide 6 and 66, polypropylene and polyester (PET). The deal provides Ascend with a consistent supply of post-consumer recycled materials for its product portfolios of sustainable polyamides.

Solvay and Orbia forming PVDF joint venture in North America

November 3, 2022 — Solvay and Orbia (Mexico City, Mexico; www.orbia.com) announced their entry into a joint venture (JV) framework agreement to create a partnership for the production of suspension-grade polyvinylidene fluoride (PVDF). The total investment is estimated to be around $850 million. Solvay and Orbia intend to use two production sites in the U.S. for the JV, one for raw materials and the other for finished products. Both plants are expected to be fully operational by 2026.

BASF acquires Cargill's canola-seed plant in Idaho Falls

November 3, 2022 — BASF SE (Ludwigshafen, Germany; www.basf.com) is expanding its high-oleic canola-seed production and processing business in North America through its acquisition from Cargill, Inc. (Minneapolis, Minn.; www.

cargill.com) of a seed production facility located in Idaho Falls, Idaho.

Hexpol to acquire U.S.-based thermoplastics firm

November 2, 2022 — Hexpol AB (Malmö, Sweden; www.hexpol.com) has signed an agreement to acquire the entirety of McCann Plastics LLC, a company specialized in niche thermoplastic compounds, with special focus on roto-molding applications. McCann operated two sites in Ohio. The acquisition price amounts to $120 million.

Clariant completes acquisition of BASF's U.S. Attapulgite assets

November 1, 2022 — Clariant AG (Muttenz, Switzerland; www.clariant.com) has completed the acquisition of BASF's U.S.-based Attapulgite business assets for $60 million in cash. The transaction includes the transfer of land, as well as mining rights, a processing facility and inventories, which will be integrated into Clariant's Functional Minerals business. The newly acquired Attapulgite business is one of the largest miners and producers of attapulgite in North America. It encompasses mining operations in Georgia and Florida, as well as processing operations in Quincy, Florida.

Dorf Ketal to acquire Clariant's North American Land Oil business

October 28, 2022 — Dorf Ketal (Mumbai, India; www.dorfketal.com) agreed to acquire Clariant's North American (NORAM) Land Oil business, a provider of chemical technologies and services to the North American oil-and-gas industry. Once completed, The acquisition includes manufacturing sites in Bakersfield, Calif. and Midland and Black Hills, Tex.

Arkema to divest phosphorus derivatives business

October 28, 2022 — Arkema S.A. (Colombes, France; www.arkema.com) its intent to divest its Febex business to Prayon S.A. (Engis, Belgium; www.prayon.com). At its operating base in Switzerland, Febex manufactures phosphorus derivatives, such as high-purity phosphoric acid, sodium hypophosphite and derivatives, which are used primarily in electronics and in pharmaceuticals products.

Albemarle acquires Guangxi Tianyuan New Energy Materials

October 28, 2022 — Albemarle has completed the acquisition of Guangxi Tianyuan New Energy Materials Co., for approximately $200 million. Located near the Port of Qinzhou in Guangxi, acquired assets include a lithium-conversion plant with a conversion capacity of up to 25,000 m.t./yr lithium carbonate equivalent (LCE). The plant can produce battery-grade lithium carbonate and lithium hydroxide.

Evonik sells its TAA derivatives business to SABO

October 24, 2022 — Evonik Industries AG (Essen, Germany; www.evonik.com) is selling its triacetonamine (TAA) derivatives business to SABO S.p.A., including production sites in Marl, Germany and Liaoyang, China. SABO manufacturers light stabilizers, for which TAA derivatives are an essential raw material. ■

Mary Page Bailey

Monitoring and Control Improves Dust Handling

As dust collection becomes an integral part of chemical processes, monitoring and other technologies promote efficiency and performance

Dust control has always been important in the chemical process industries (CPI) due to the often toxic and combustible nature of the chemicals being processed. As budgets and exposure limits continue to tighten, monitoring and control and efficiency-minded technologies are emerging as the latest trends in dust-control systems.

"Old-school dust collection served an important purpose — keeping employees and facilities safe — but it was often set up and not thought about again until it was ineffective. Today, dust control is considered an integral part of the process because it impacts safety, product quality and the efficiency and productivity of the plant," says Andy Thomason, senior applications specialist with Camfil Air Pollution Control (APC) (Jonesboro, Ark.; www.camfilapc.com).

U.S. Air Filtration

FIGURE 1. Having a dust-collection solution specifically engineered for an application will ensure factors such as the amount of dust generated, characteristics of the dust, dust particle size and temperature are taken into consideration so processors end up with an efficient and effective dust-control system

"Processors are beginning to apply monitoring and connectivity to dust-control systems because it provides insight. The more information they can gather, the more they can trend that data and make better decisions about controlling the collector so that it provides the safest, most effective and most efficient operation."

The importance of dust control

The CPI is full of dusts — moving dusts, grinding dusts, conveying dusts — and many of these dusts cause challenges. These challenges include housekeeping issues, cross contamination and product quality problems, employee or environmental exposure risks and fire or explosion hazards, so dust must be controlled.

"Control of potentially toxic and combustible dust generated in chemical-processing facilities is essential to protecting employee health and maintaining product quality, while preventing a possible explosion down the line at the dust collector itself," notes Scott Pitts, vice president of engineering and equipment sales with U.S. Air Filtration, Inc. (Tyler, Texas; www.usairfiltration.com).

However, control is not as easy as setting up a dust collector and turning it on. "There are many challenges and these can vary from process to process and facility to facility. Factors such as the amount of dust generated, characteristics of the dust, dust-particle size and temperature all play a part in the design of the dust control solution," Pitts continues. "Having a dust-collection solution specifically engineered for your application will ensure all these factors are taken into consideration" (Figure 1).

J. Kirt Boston, global manager of Torit product technology with Donaldson Co. (Bloomington, Minn.; www.donaldson.com) agrees: "Properly employing dust-control strategies eliminates the majority of nuisance-dust releases. That's what a system design aims for: How do you avoid allowing the contaminant to get out and become an uncontrolled issue that can create problems related to employee and facility safety, product quality and housekeeping? How do you effectively control a contaminant using the least amount of air, energy and space? How do you avoid the potential risks associated with uncontrolled dust in a way that is less intrusive and less costly?"

Monitoring and control

Processors rely on dust control to remain in compliance and avoid safety issues, while also ensuring product quality. For this reason, dust-control systems have become a crucial part of the process. "In many cases, if the dust collector stops working properly, the whole process must be shut down because they can move out of OSHA [Occupational Safety and Health Administration] or EPA [U.S. Environmental Protection Agency] compliance, create fire or combustion hazards or have cross-contamination or quality issues if the dust collector starts spewing dust into

Camfil APC

FIGURE 2. Camfil APC's GoldLink Plus filter monitoring system offers differential-pressure monitoring, but the system can be customized to incorporate several monitoring points from a single or multiple collection system

RoboVent

FIGURE 3. Nederman Insight is a cloud-based IIoT platform designed specifically for SmartFilter systems that provides real-time monitoring, visualization and tracking of system performance, including customized dashboards, alarms and reports

the facility or environment," explains Camfil's Thomason. "For this reason, users are applying more monitoring and connectivity to the collectors. This enables operators to continue to do their job while also being alerted to potential problems with the dust collector before they have to shut down the process."

There are a variety of ways monitoring can be deployed on dust-collection systems, with most suppliers offering some type of monitoring technology. For example, Camfil APC offers the GoldLink Plus filter monitoring system, which transmits real-time data to the cloud over an encrypted cellular network (Figure 2). The standard model offers differential-pressure monitoring, but the system can be customized to incorporate several monitoring points from a single or multiple collection system. Monitoring points can include data from level sensors, particulate-matter counters, compressed air and more. End users are able to customize alerts to notify operations if the system is operating out the ordinary or nearing a failure, enabling more efficient and effective operations. Alerts can be sent to notify personnel of any out-of-system specifications. "The more information gathered and analyzed, the better the facility can implement measures to ensure they continue to run smoothly, safely, efficiently and cost effectively," says Thomason.

Similarly, Schenck Process LLC (Kansas City, Mo.; www.schenckprocess.com) is developing a cloud-based monitoring solution that can also be used to locally monitor dust collection at the plant. "Our system can be beneficial for plants wanting to monitor system performance to save money on the significant costs associated with replacement bags and filter elements," says Steve McConnell, director of filtration with Schenck Process. Typically, most processors have planned shutdowns during which they change out these elements, not knowing how long the filters could last; however, the monitoring system can trend their specific applications and provide a better idea of the filter element's true life. "Maybe they can extend their shutdowns if the filter elements have a longer lifetime, which saves the cost of replacing filters that don't need it. Or, maybe they should be shutting down more often to prevent issues with compliance or product quality."

The technology can also be applied in an effort to avoid downtime on critical processes where the collectors operate as a receiver off a process such as a drying, milling or cutting. "If those baghouses have issues, the whole plant is often shut down," says McConnell. "So, in these applications, we would monitor many different parameters such as the air velocity, product flow, differential pressure, level indication, emissions, temperature, blower speed and others. Monitoring these points can help avoid a costly downtime event and help them remain in compliance with OSHA and EPA regulations while avoiding other risks such as fire and explosion."

Some users are employing monitoring for energy conservation, as well, notes Mike Meyer, application engineer with RoboVent (Sterling Heights, Mich.; www.robovent.com). "In addition to monitoring for effectiveness, we can also use these technologies to monitor for energy conservation by putting sensors in the system, ductwork, hoods and dust collectors to determine if the system is operating as it was designed at each collection point," he says. "If dampers have been opened, filters are overloaded or the air velocity has dropped for some other reason, this means that not only could you have contaminant dropout issues, but you could be wasting electricity as the system works harder to collect and move the dust. Trending this data could lead to significant savings at a time when processors are working with tight budgets and sustainability is a goal."

RoboVent's parent company, Nederman, offers SmartFilter technology which features sensors that collect key performance metrics throughout the dust-collection system and visualizes them on both the local controls and on a cloud-based industrial-internet-of-things (IIoT) platform, where data analytics can be used for predictive maintenance and system optimization (Figure 3). Additionally, processors are able to monitor live system performance, receive timely alerts when action is required and auto-

Donaldson

FIGURE 4. The Donaldson Torit PowerCore CP Series dust collector offers a smaller size because it uses significantly smaller and more powerful filter packs than baghouses to provide better dust collection and lower operational costs

DUST-REMOVAL EQUIPMENT ENABLES MORE STABLE RECYCLING PROCESSES

While dust control plays an important part in the CPI, the plastics industry has its own set of dust-related woes, which require dust removal, also called de-dusting. The goal in plastic processing is to remove dusts that interfere with process stability and product quality.

"While our de-dusting systems do have dust collection systems that sometimes include filters and cyclones, they are actually dust removers," says Joe Lutz, director of sales and marketing for Pelletron Corp. (Lancaster, Pa.; www.pelletroncorp.com). "They are used to remove fine dusts from the granular materials that are used to produce plastic parts versus dust collectors that separate dust from the air."

Fine dusts are a challenge for plastic processors that make light- or clear-colored parts, such as eyeglass lenses and polyethylene terephthalate (PET) water bottles, because the fine dusts and long strips of melted plastic, called angel hair or snakeskin, get mixed in with the pellets they are melting to make plastic parts and burn during processing. This causes visual defects in the finished product. "What makes this dust issue different is that the challenge is on the yield side versus on the emission side," says Lutz. "And that requires a different technology, such as the Pelletron DeDuster, which uses an electromagnetic coil on the inlet to move small, micron-sized particles before the pellets are washed with air to strip those particles off the larger pellets (Figure 6). The process removes fines to a level well below the industry standard. Further, the technology takes care of both fine dusts and angel hairs with one piece of equipment. Removing both contaminants used to require two pieces of equipment: one to remove the fine dust and a second to separate the angel hairs."

FIGURE 6. The Pelletron DeDuster uses an electromagnetic coil on the inlet to move small, micron-sized particles before the pellets are washed with air to strip those particles off the larger pellets. The process removes fines to a level well below the industry standard and enables higher-quality plastic recycling

Lately, de-dusting technology has been enabling recycling processes to work better. "Currently, there is a great demand to become more responsible and circular with plastics," says Lutz. "While recycling plastic materials has always been a great idea, it's historically a difficult process due to the variety of materials that come in for recycling. There are challenges associated with processing a dusty, variable-quality material into a flawless, perfectly clear, perfectly shaped high-quality product like PET bottle preforms."

The Pelletron DeDuster helps keep the material as uniform as possible by removing very fine dusts from the regrind material. "We enable a much more stable recycling process that results in the ability of recyclers to produce high-quality parts and that is what every chemical engineer desires." ❐

mate performance reports to maximize productivity and maintain the system as efficiently as possible.

Efficiency-minded technologies

At a time when budgets are tight and sustainability is a goal, many processors are looking to reduce costs associated with dust collection and that means many are considering moving away from centralized dust collection toward localized collection, says Donaldson's Boston. "One of the trends we are seeing is facilities bringing dust control closer to the place where the dust is being generated," he says. "They want to design a system that can be deployed locally."

For example, in the grain industry, they might have a grain elevator that serves an offshore loading facility and that elevator might have four parallel lines of conveying to fill all the silos. In the past, they would have all been connected to a single, central collector, but today they may have four separate systems because they don't need to run all four lines at the same time.

"This means that instead of running the air volume for four dust control lines, they only need to run enough air for one, so they aren't wasting as much air or energy. In addition, by moving away from centralized systems to a dedicated system, they may have opportunities to recover valuable product and return it to the process. For example, they may put a bin vent

FIGURE 5. MCF PowerSaver technology uses a positive-displacement blower package, which requires 50% of the energy of a typical pulse-jet system, providing a significant energy savings

on each bin, which allows the dust to be returned to the bin. In addition to avoiding the loss of valuable product, they are only running the collector and air when that particular bin is being filled. Our PowerCore bin-venting product is key here" (Figure 4).

Another advantage that comes with locating the collectors close to the generation source is that all the ducts that were used to route the dust from where it was released to where it was collected, start to go away, explains Boston. "Beyond saving on installation and maintenance, it took energy to pull the air through all those ducts, so by putting the collector closer to where the dust is generated, you use less energy. There are definite energy advantages to decentralizing dust collection."

Also addressing energy efficiency, Schenck Process offers its MCF PowerSaver Filters (Figure 5). "This filtration system is not reliant on plant compressed air to clean filter elements. Instead, we supply the cleaning air, which uses less horsepower and is more efficient in high-flow and larger applications," says McConnell. "MCF technology uses its own positive displacement blower package, which requires 50% of the energy of a typical pulse-jet system, providing a significant energy savings at a time when budgets are tight and businesses want to reduce their carbon footprint." ■

Joy LePree

Level Measurement & Control

Magnetrol, part of the Ametek Sensors

Baumer Group

VEGA Grieshaber

A new level detector for multiphase applications

Multiphase level measurements exist throughout chemical process industries (CPI). They are especially significant in the oil-and-gas and petrochemical sectors due to the value derived from effectively separating water and hydrocarbons. While level instrumentation has come a long way in measuring liquids of all varieties, multiphase level measurement remains a towering challenge and a considerable opportunity. The new Genesis multiphase detector (photo) encompasses several significant engineering accomplishments. It is designed to measure multiple phases in applications with thick and dynamic emulsion layers: vapor phase; total level (for example, hydrocarbon liquid); top of emulsion layer; bottom of emulsion layer (for example, water level); and sediment. The device features 24-V d.c. input with four 4–20-mA outputs (including HART) for convenient control of total level, top of emulsion, water level and sediment. It uses proprietary software algorithms for interpreting signals. Changing media characteristics have no effect on level measurement. Probes are available for temperatures of 400°F and pressures of 1,000 psi (200°C and 70 bars). The electronics can be remote-mounted up to 100 ft (30 m) away from the probe. — *Magnetrol, part of the Ametek Sensors, Test and Calibration, Aurora, Ill.*
www.magnetrol.com

This new level sensor can even detect process water

The new sensor CombiLevel PLP70 (photo) automatically adapts to varied media and offers user-friendly process monitoring thanks to the large touch display. The PLP70 potentiometric level sensor is able to measure media of low minimum conductivity — down to 10 microsiemens (µS). This is well below conventional limits, and allows for use in media such as process water, the company says. The device has an IO-Link interface, and it allows accurate and reliable measurement for precise monitoring of filling levels in feeding containers and storage tanks. Thanks to the short response time (less than 100 ms), the PLP70 is ideal for highly dynamic processes like fast changing levels in filling lines. Applications include industrial (process tanks, cleaning and filter plants, water treatment installations, agricultural machinery) to hygienic (filling lines, storage and buffer tanks, process tanks, filter and cleaning facilities). The CombiLevel PLP70 with standard digital IO-Link interface and analog output was launched at drinktec (Munich, September 12–16). — *Baumer Group, Frauenfeld, Switzerland*
www.baumer.com

This radar sensor is suitable for virtually any application

The new VegaPulse 6X (photo) radar level sensor offers a self-diagnosis system that immediately detects damage or interference to ensure significantly higher availability and safety. It has new radar-chip technology, with expanded application possibilities and simpler operation. In addition to SIL certification, the matter of cybersecurity has also been taken fully into account. The device complies with security standard IEC 62443-4-2, which specifies the strictest requirements for secure communication and access control. The VegaPulse 6X is said to be the one sensor that can handle any application. In the future, the user will no longer have to worry about the technology, frequency or instrument version. Even setup and commissioning have been reduced to a minimum, requiring just a few clicks and basic application parameters. In many cases, all application-specific settings can be made in the device before it leaves the factory. — *VEGA Grieshaber KG*
www.vega

Level switches designed for powder challenges

The CL-10 G Series level detectors (photo; p. 19) provide for high-level overfill protection or can monitor low and intermediate points. They operate with accurate and consistent results on problem applications that have a tendency to bridge and "pack-out." G Series detectors han-

dle precipitated and fine, lightweight chemical powders with a bulk density as low as 1 lb/ft^3 with great success. They easily manage a variety of heavier bulk solids in the density range of 10 to 15 lb/ft^3. The level detectors can operate in dusty environments, and specialized units handle temperatures exceeding 300°F. All level detectors are calibrated at the factory and do not require any field calibration before installation. Approved for Class I, Group D; Class II, Groups E, F & G; and Class III services. The level switch is mounted through a ¾-in. half-coupling at the point of desired level detection, eliminating costly flanges, float chambers or fittings. — *Automation Products Inc., Dynatrol Division, Houston*
www.dynatrolusa.com

Automation Products

This diaphragm level switch alerts when bins are full

The BM-25 diaphragm switch (photo) is a rugged pressure switch for high- or low-level alerts in bins containing non-hazardous, free-flowing dry materials. The BM-25 alerts operators to high or low levels or when chutes or conveyors are clogged. It is a simple and convenient way to stop overflowing product or wasting valuable material in the bottom of a bin. Suitable for bins and silos, the BM-25's simple mechanism activates a sensitive micro-switch to indicate when material reaches the level of the switch in the bin. The pressure switch alerts when it senses high or low levels. Typically, it is wired to a light, horn or alarm panel. The switch has a silicone diaphragm and is enclosed in a nylon housing, designed to increase durability. There are models to mount internally or externally. The corrosion-free polymer construction makes the device suitable for agriculture cooperatives or any business storing dry bulk solids. It monitors the level of material like corn, soy, wheat, wood, plastic, crops, rice, powders and landscaping materials, as well as aggressive chemicals like fertilizer pellets. — *BinMaster, Lincoln, Neb.*
www.binmaster.com

BinMaster

UWT

JUMO

Capacitance sensors now have IO-Link outputs

A range of new Capanivo 7000 models of level sensors now include IO-Link technology on board. The capacitive level-limit switches (photo) are used as a full, demand or empty detector, as well as for leakage detection and interface measurement. The sensor is suitable for installations in all kinds of liquids, pastes, foams and slurries. This very compact capacitive level detection handles a variety of applications. The probe is made of chemically resistant polyvinylidene fluoride (PVDF), and has an M12 connector. Hygienic design and food-grade materials are available, and the device is suitable for steam-in-place (SIP) and clean-in-place (CIP) applications at temperatures up to 150°C. — *UWT LLC, Memphis, Tenn.*
www.uwtgroup.com

Measure filling level with the highest safety standards

This company's instruments for the detection and measurement of process-critical point levels and filling levels for liquids now has solutions for up to safety integrity level (SIL) 2 according to IEC 61508. This system is based on the products of the company's NESOS series (photo), which is available in various expansion stages to suit the user's requirements. Flexible options are available, including the SIL-qualified sensor with all required safety-related characteristic values, SIL-certified sensors and the certified measuring point. The complete solution in the "filling level" field can also reliably detect line faults, such as short-circuits and cable breaks, ranging from the sensor to the actuator. Solutions can also be implemented in combination with applications in explosion-protected areas (intrinsically safe [Ex i] and flameproof enclosure [Ex d]), as well as in shipbuilding. As a result, possible applications include the field of liquid gas and hydrogen, steam boilers, bioreactors or solvent purification plants. — *JUMO GmbH & Co. KG, Fulda, Germany*
www.jumo.net ■

Gerald Ondrey

New Products

Upgraded fluid-bed processors feature better process control

This company has upgraded its Vibro-Bed fluid-bed processor (photo) with new features designed to regulate pressure and temperature more efficiently for faster material drying and increased throughput. Fluid-bed processors dry, moisturize, heat or cool bulk material by causing it to vibrate on a screen or perforated surface within a rising column of heated, chilled or moisturized air. In addition to faster drying, the Vibro-Bed's upgraded controls make it easier for operators with minimal training to run batch or continuous material processing. An energy-efficient circular design utilizes 100% of the surface area to optimize airflow for faster drying, less waste and a more consistent product, according to the company. The Vibro-Bed product range includes eight compact models ranging from 24 to 84 in. (610 to 2125 mm) in diameter. Configurations are avilable for scalping, de-dusting, agglomerating or de-agglomerating materials while they are dried, cooled or moisturized to save on the cost of operating separate equipment. — *Kason Corp., Millburn, N.J.*
www.kason.com

Kason

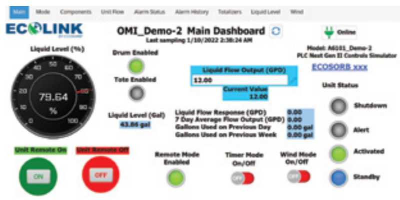
Streamline quality control with this three-in-one analysis device

Easy Vis (photo) is a new instrument that analyzes liquid, translucent samples for their optical spectrum, color and water parameters. Combining these critical measuring tasks into one device, Easy Vis takes over the measuring tasks of up to three instruments: a colorimeter, a spectrophotometer and special measuring devices for water testing, such as titration. Analysis results appear onscreen within seconds. Easy VIS is suitable for use in quality-control laboratories at small manufacturers in the food-and-beverage industry, environmental testing labs or any industry needing quality control for products or process water or wastewater streams. The Easy VIS is used during multiple steps of the production process: for inspection of raw materials; for quality control of semi-finished and finished products; or for testing the water quality of wastewater. These capabilities are especially valuable for laboratories that previously sent out samples to an external laboratory, because they can now conduct in-house analyses. Easy VIS operates within a wavelength range of 330 to 1,000 nm. The light source is an easy-to-replace tungsten lamp. — *Mettler-Toldeo GmbH, Nänikon, Switzerland*
www.mt.com

Mettler Toledo

Remote monitoring and control of odor-control systems

Ecolink (photo) is an online portal for remote monitoring and control of this company's industrial odor-neutralization systems. With this advancement, users can now manage their equipment from anywhere with any device capable of hosting a web browser, such as a smart phone, tablet or computer. EcoLink provides the ability to remotely start, stop and change vaporization-system operating mode, identify low product levels and rack and trend flowrates, energy use, downtime and other key performance indicators (KPIs). Additionally, EcoLink can send alerts and notifications to an operations team, adjust product dosage to coincide with fluctuating odor-producing periods and encrypt data for transit and storage. — *Ecosorb, Palatine, Ill.*
www.ecosorbindustrial.com



Ecosorb

Better stress distribution with this tool design

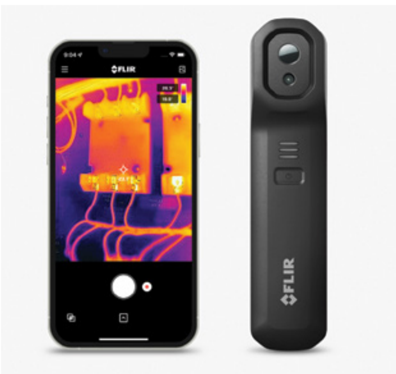
This company's Wright Drive 2.0 socket design is said to distribute contact stress more effectively than other wrench systems. The Wright Drive 2.0 12-point design has up to 10 times more tool-to-fastener contact area than conventional 12-point wrenches. The design improves fastener torque load while decreasing rounding and distortion of the fastener. The Wright Drive 2.0 six-point design (photo) moves the contact area away from the corners, creating greater strength and more torque. Its circle diameter reduces fastener rounding and allows better grip on undersized fasteners and previously rounded corners. — *Wright Tool Co., Barberton, Ohio*
www.wrighttool.com

Wright Tool

Siemens

Emerson Automation Solutions

Heinkel Drying & Separation Group



Teledyne FLIR

New versions available in this line of Ethernet switches

The Scalance XC-/XR-300 (photo) series of Industrial Ethernet switches has been upgraded with a higher port density, which allows many devices to be connected within large network infrastructures. Thanks to their high-bandwidth ports (up to 10 Gbit/s), the new models also enable various OT network applications for data, voice, video and Profinet. With the Industrial Ethernet switches, OT networks are easily connected to IT and thus enable more flexible production. The new switches thus replace the portfolio of the current Scalance X-300 series and carry the model designation Scalance XC-/XCM-300 in the compact version and Scalance XR-/XRM-300 in the 19-in. version. The new Scalance devices were first presented at the Smart Production Solutions (SPS) fair in Nuremberg, Germany in November. — *Siemens AG, Munich, Germany*
www.siemens.com

This pressure transmitter offers mobile responsive connectivity

The enhanced Rosemount 3051 pressure transmitter (photo) features user interfaces that have been redesigned to provide a simplified, task-based menu structure with common navigation across host and configuration tools for a faster, more intuitive user experience. The new, high-contrast, backlit display can operate in eight different languages, and its visual icons give better insight to transmitter status. The new Bluetooth wireless technology simplifies configuration and service tasks without having to physically connect to a device, eliminating the need to climb ladders or tanks, get hot-work permits or enter hazardous locations. With built-in password protection, users will have an encrypted data connection from the transmitter to the mobile device or configuration tool. Additional transmitter upgrades include capabilities that have historically been limited to flowmeters and level devices. Now, operators can easily configure the device to measure flowrate, as well as track total flow. Volume measurements are also possible for common tank styles or even customized tanks that require a strapping table. — *Emerson Automation Solutions, St. Louis, Mo.*
www.emerson.com

Combine multiple steps in a single vacuum mixer-dryer unit

The Bolz conical vacuum mixer-dryer (photo) has been specifically engineered to meet the strictest requirements for vacuum processes by combining multiple processing steps into a single fully enclosed processing system that delivers safer operations by utilizing fixed permanent connections for all aspects of the process. The unit's applications include drying, de-aeration, crystallization, homogenization, heating, cooling and injection of liquids and gases. The Bolz technology includes orbiting-arm or central shaft agitator designs, a heated agitator to reduce drying times and full clean-in-place (CIP) systems. The low-energy units feature three-dimensional mixing, as well as variable volume filling down to 20% of the unit's total volume. Sizes range from 1- to 5,000-L working volumes. — *Heinkel Drying & Separation Group, Swedesboro, N.J.*
www.heinkelusa.com

The first truly wireless mobile infrared camera

FLIR One Edge Pro (photo) is said to be the first truly wireless thermal-visible camera for mobile devices. Unlike previous models, the reimagined FLIR One Edge Pro doesn't need to be physically connected to its companion mobile device, nor does it have separate models for specific operating systems, providing maximum flexibility for thermal inspections. The IP54-rated FLIR One Edge Pro has a spring-loaded clip designed to allow operators to attach the camera to many types of mobile phones and tablets. Thanks to the combined Bluetooth and Wi-Fi connection, users can operate the Edge Pro up to 30 m away from their mobile device, providing the flexibility to effectively inspect hard-to-reach places or those scenarios requiring greater standoff distances to maintain operator safety. The device features a 160×120-resolution thermal-imaging camera paired with a visible camera. The MSX image-enhancement feature overlays the edge detail of the visible camera onto the thermal image without sacrificing any thermal data within the image. — *Teledyne FLIR LLC, a Teledyne Technologies company, Wilsonville, Ore.*
www.teledyneflir.com

New NDT technique for inspection of composites

Insono is a new non-destructive testing (NDT) technique for the inspection of composite repairs applied to metallic components. Insono complements this company's Technowrap range, and provides operators with assurance required by the regulatory bodies. It also allows for the extension of defined-life repairs, reducing waste while avoiding carbon emissions from traditional steel-replacement alternatives. Validated by The Welding Institute (TWI) with patent and U.K. accreditation pending, the portable hand-held equipment and specifically designed probes (photo) allow for inspection of all geometries, including complex configurations, and can easily be deployed in the field in hard-to-reach locations. — *ICR Integrity. Aberdeen, U.K.*

ICR Integrity

www.icr-world.com

Dual-action inspection and weighing for packaging

This company has developed a new unit that combines metal detection and weighing to streamline product packaging applications, leading to improved reliability, throughput rates and accuracy. The Metal Detector Checkweigher Combo (photo), unveiled at Pack Expo in Chicago, employs a high-performance weigh cell that uses electromagnetic force restorations (EMFR) technology, instead of the traditional strain gages used in other scales. Moving along a conveyor, the package is first inspected for metal. If traces of metal are detected, the package is automatically rejected without slowing down the line. As pure packages continue along the conveyor, they are then checked for accurate weight. If it is either over or under the prescribed weight, then it is rejected into a different bin. — *Bunting-Newton, Newton, Kan.*

Bunting-Newton

www.buntingmagnetics.com

A portable conveying system for pharma and food products

This company has introduced a new manual dumping system with integral conveyor and separate dust collector (photo, p. 24), which is suitable for dairy powders, pharmaceutical products and contamination-sensitive bulk foods. Designed and finished to 3-A sanitary standards, the system is composed of a manual dumping station with a surge hopper, a flexible screw conveyor and a support boom on a caster-mounted frame, plus a separate, mobile dust-collection system that can be configured alongside or remotely. The mobile system can serve multiple func-

Flexicon

Chemline Plastics

tions throughout the plant, and then be rolled to a washdown station and storage area. A dust hood is mounted to the floor hopper with quick-release clamps, and is equipped with an internal baffle and air-vent port for efficient dust collection. A support tray allows operators to stage manual additions from handheld sacks before dumping material through a grate fabricated of powerful rare-earth neodymium-iron-boron magnet material. The hopper is equipped with a mechanical agitator assembly to promote uninterrupted flow into the charging adapter of a 10-ft flexible screw conveyor with a stainless-steel screw engineered to handle the conveyed product. Fully enclosed in a polymer tube inclined at 45 deg, the flexible screw is the only moving part contacting material, and is driven by an electric motor beyond the point of discharge, preventing material contact with the motor shaft seal. — *Flexicon Corp., Bethlehem, Pa.*
www.flexicon.com

Lightweight, corrosion-resistant cyclones for water treatment

HN Series Hydro Cyclones (photo) are designed to separate sand and other solids from water using centrifugal force. HN Series Hydro Cyclones are suitable for use in pre-filtration applications in membrane water-treatment systems. The HN Series is offered in three sizes. The 1-in. cone is made of glass filled polyamide (PAG), while the 2- and 3-in. cones are made of glass filled polypropylene (PPG). Plastic construction means that these units are lightweight and resistant to corrosion and abrasion. Water enters the filter tangentially to the cone body and is accelerated by circular motion. The sand or other solids are pushed against the cone side walls and by centrifugal force and settle into a bleed tank while clear water flows up through the central outlet. The tank may be flushed occasionally using the supplied ball valve. — *Chemline Plastics Ltd., Thornhill, Ont., Canada*
www.chemline.com ■

Mary Page Bailey

Discovery and Re-discovery of Mechanochemistry

A reclusive expert of 19th-century photography laid the foundation for mechanochemistry, a once-ignored field that is re-emerging in 'green chemistry' applications

Clay Cansler and Roger Turner, Science History Institute

For decades in the late 1800s, Carey Lea had been fascinated by the chemistry of photography, and had studied silver solutions, which were essential to capturing images at the time. In a series of experiments related to photographic film chemistry, Lea developed insights about how mechanical forces can initiate chemical reactions and revealed that mechanical forces can spawn unique reactions and products.

Over the course of three years, Lea (Figure 1) established mechanochemistry as a stand-alone field. But the 1890s — when Lea published his foundational works on mechanochemistry — were a transformational time in industrial chemistry, and the research and development model was shifting from curious individuals inventing in private laboratories, to collaborative teams of researchers working in university- and industry-backed laboratories.

The circumstances of Lea's work — he was without scientific "heirs" and was detached from a growing cadre of mainstream chemists and engineers building the modern chemical industry — meant that his ideas languished unappreciated for much of the 20th century. Now, however, the growing push for a sustainable chemical industry is driving a resurgence of research into the use of mechanical forces in place of heat and solvents — ideas that Lea pioneered more than a century before.

Photographic chemistry

Born into a wealthy and intellectual Philadelphia family in 1823, Lea at first pursued a career as an attorney, but health problems disrupted that path, and Lea retreated from public life, returning home to study analytical chemistry. He would eventually build possibly the best private chemistry laboratory in the country at the time. Lea led a largely reclusive life, mostly working in his Philadelphia lab.

During Lea's life, photography was a revolutionary technology, and the chemistry of photography became the focus of Lea's work by the 1860s. He generated information about light-sensitive emulsions for exposing images and the chemical processes for developing them. In 1868, he published "A Manual of Photography," which became a standard reference work for photographers and others trying to understand the art and science of the technology.

Lea's extensive work in photography was highly influential to a young George Eastman, who would go on to develop a dry photosensitive coating applied to rollable, paper-based film that was used in the Kodak camera he introduced in 1888.

Mechanical forces

Silver was always a key element in photographic chemistry, and no one knew its properties like Carey Lea. It was through his investigation of silver salts and colloids that Lea began thinking about the effects mechanical force can have on chemical reactions.

In 1886, Lea's observation of discolored silver that he hypothesized was due to physical forces launched a careful study of silver halides and mechanical force, resulting in four papers that marked the first systematic investigation into mechanochemistry.

At first, Lea explored samples of a silver colloid he developed, finding that both light and physical force could produce similar transformations. For example, pressing a glass rod across a photographic plate covered with silver colloid created developable images, just as if the plate had been exposed to light. In this way, Lea demonstrated that mechanical energy, including static pressure and shearing force, was capable of disrupting silver halide molecules.

During 1893 and 1894, Lea published three more papers that extended his investigations of mechanical force on chemical bonds, then another paper that took aim at the common 19th-century dogma that chemical changes could not be brought about by "mechanical impulse." He showed that mechanical force could break down some materials just as heat would — sometimes even more efficiently. Even more significantly, Lea found that mechanochemistry could do things that were impossible with thermochemistry. For instance, heating mercuric chloride made it sublime (solid to gas), but grinding it decomposed the molecules.

FIGURE 1. The engraving here depicts chemist Carey Lea in the years of his mechanochemistry discoveries

Taken together, his papers show that Lea was able to discriminate between the effects of heat and mechanical action while quantifying the results, work that made him "the true founder of mechanochemistry," according to Laszlo Takacs, a metallurgist and physics professor at the University of Maryland, Baltimore County, who published a biography of Lea in 2003. "He not only showed that mechanical action was capable of inducing chemical changes . . . he also proved that these changes were sometimes different from those produced by heat," wrote Takacs.

Industrial chemistry shift

But the social structure of chemistry had changed substantially over Lea's lifetime, and the influence of gentleman scientists, working in personal laboratories, waned. Research, instead, became centered in labs backed by universities, government bureaus and industrial companies. Expanding universities created a growing population of credentialed chemists, and as chemistry grew, the approaches that thrived were the ones recognized by this new generation of experts. Solvents and

heat became familiar tools that both researchers and engineers successfully controlled to produce chemicals at industrial scale.

Mechanochemistry was largely ignored by the industry. Lea lacked the protégés and collaborators who could have integrated his insights into industrial-scale production. New chemical plants were designed by chemical engineers trained by solvent chemists working in university-based education programs.

Renewed interest

During the 20th century, chemists harnessed solvents and heat to develop the broad range of chemicals that form the foundation of today's material world. But they worked in a time when heat was cheap and disposing of toxic solvents was often cheap, too, and environmental consequences were not fully appreciated. By the time Lea died in 1897, the course of chemistry had been set, and mechanochemistry, the brainchild of a dedicated but solitary chemist, was left in its wake.

Now, however, there are examples of modern researchers and engineers working to better understand, and use, chemical reactions under mechanical forces, harkening back to Lea's initial work in the 1890s. For example, metallurgists have used the forces present in ball milling for decades to get nickel to accept oxide particles that were rejected during melting. These strengthened alloys can withstand extreme temperatures.

In other cases, mechanochemists hope to replace solvent-based production with mechanical processes that require less energy and produce less waste. Chemists in Europe have used an extrusion process consisting of intermeshing screws that grind together reactants to replace heat and solvents in the producing well-known muscle relaxants and antibiotics.

Although mechanochemistry was a path not taken in the 20th century, and remains largely experimental, it may be a vision of the future. ■

Edited by Scott Jenkins

Clay Cansler is the Science History Institute's (SHI; Philadelphia, Pa.; www.sciencehistory.org) editorial director. **Roger Turner** is the curator of instruments and artifacts in the SHI's museum.

Liquid-Liquid Extraction Basics

Department Editor: Scott Jenkins

Liquid-liquid extraction (LLE) is a separation technique that exploits differences in the relative solubility of compounds of interest (the solute) in two immiscible liquids — most often an aqueous phase and an organic solvent. This one-page reference reviews basic information about how the LLE process works, where it is used and what equipment is required.

Uses

LLE is used across many sectors of the chemical process industries (CPI). In cases where distillation can separate materials economically, an LLE process would not generally be used, but in cases where distillation is not feasible, LLE is often the best solution. Distillation may not be feasible because of high process complexity, heat-sensitive materials, low volatility or prohibitive energy requirements. LLE can be used to break azeotropes, and in place of a complex distillation sequence.

Applications for which LLE is used include the following: separation of products from fermentation and algae broths; removal of high-boiling organic compounds from wastewater; recovery of reaction products caprolactam and adiponitrile in nylon production; extraction of flavors and fragrances in the food industry; neutralizing acids and bases; decaffeination of coffee and tea; and others.

LLE process

In LLE, a liquid stream containing a compound of interest is fed into an extractor, where it comes into contact with a solvent. To allow phase separation, the solvent and liquid stream are immiscible, or only slightly miscible, and have different densities. The two components are mixed to promote close contact, allowing the transfer of the solute into the solvent phase (Figure 1). The feed containing the solute is introduced into the extractor, where it transfers into the solvent. The raffinate is stripped to remove solvent in a separate operation, typically a stripping column. The solvent in the extract stream is typically recovered in a distillation column.

Equilibrium

Before setting up an LLE process, equilibrium data should be generated to define how the solute of interest behaves in the two immiscible phases. The data generated can then be used to construct a curve for the partitioning behavior of the solute (an equilibrium curve).

Data for LLE are generated using the shake test, a method that allows for the calculation of solvent-to-feed (S/F) ratio, versus the number of stages the process will require. In the shake test method, a jacketed, round-bottom flask with a standard impeller and a bottom outlet is used. The feed and solvent are carefully weighed and added to the round-bottom flask at the desired S/F ratio. The flask is mixed for a specified time and the phases are allowed to separate. After the first mix-decant sequence, the raffinate phase is returned to the flask and fresh solvent is added at the same S/F ratio and the process is repeated to produce raffinate with the desired solute concentration (usually 4–6 times).

The data from the shake tests generate log sheets from each of the mix-decant experiments and are presented in a table that shows full-mass balances.

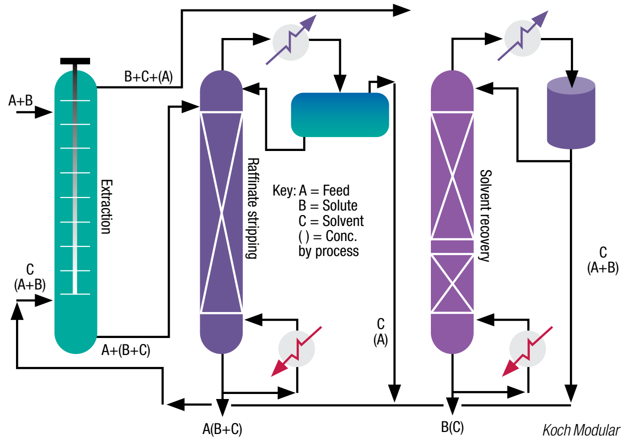


FIGURE 1. In LLE, a solute-containing liquid stream contacts a solvent

Column selection

Based on equilibrium data collected in the shake test, as well as the observed interaction between the two phases during mixing and separation, plus previous experience with LLE processes, a column type can be selected. The two main types of agitated extraction columns are rotating and reciprocating. A rotating column operates using impellers on a central shaft, plus baffling or plates (or both) to define the mixing pattern of the liquids and minimize axial mixing. A reciprocating column, on the other hand, forms disperse-phase droplets utilizing internals that reciprocate (up and down) at specified amplitude and frequency. Because of the uniform shear across the entire cross section of the column, this type of mixing is well suited for systems that emulsify easily.

A rotating column would be the first choice if the shake tests indicate a short separation time (on the order of seconds), and if the mixture of solvent and feed does not form an emulsion. Typically, these are systems with high density differences between the phases or high interfacial tension. Rotating columns can minimize capital costs. In cases where a slow-separating LLE system exists, rotating columns would not be ideal because of the high shear forces imparted by the tips of the impellers.

Reciprocating columns are used in cases where the shake tests indicate slow phase separation and if the system tends to emulsify, which typically happens with low density or low interfacial tension (or both). Reciprocating columns offer higher throughput than rotating columns due to higher open flow area and uniform shear mixing, proven to be the better choice when a significant amount of suspended solids is present in the system. ■

Editor's note: The column was adapted from: Glatz, D., Cross, B. and Lightfoot, T. Liquid-Liquid Extraction: Generating Equilibrium Data, *Chem. Eng.*, October 2018, pp. 38–42.

Pump Troubleshooting Using Video Analysis

By allowing maintenance professionals to visualize vibration on entire pump systems, video vibration analysis and motion magnification can help to rapidly diagnose vibration issues

Chad Pasho
Mechanical Solutions Inc.

Video vibration analysis, and motion magnification in particular, is democratizing complex system-level vibration testing by making it simple and straightforward for maintenance professionals to measure and visualize vibration of entire pump systems. This comprehensive technique enables rapid diagnosis of machine or piping vibration issues in minutes, and the enhanced "motion magnification" video helps decision makers genuinely understand what is going wrong with the pump and pump system, facilitating buy-in for corrective action. And because the technique is fast and cost-effective to use, any bad-actor pump qualifies for analysis, no matter how critical. This ability can help reduce the backlog of chronic vibration issues plaguing the maintenance and operations staff. With the right tools, training and personnel, video-vibration-analysis technology can become a key component in your pump-troubleshooting toolbox.

System-level vibration issues

Pumps are at the heart of many processes in the chemical process industries (CPI), moving fluids from one process to another. In nearly all instances, the pumping involves a dynamic rotating element of some kind that needs to be coupled to a static, stationary place in the facility. The combination of dynamic rotating components and static stationary components can often lead to clashes between the two — resulting in what engineers affectionately call "vibration problems."

While some of these vibration problems arise explicitly within the domain of the pump itself, many are actually due to system-level issues, such as misalignment, or problems with the foundation or piping. In these instances, it may not be the pump itself that is causing the issue, but how the pump is interacting with the rest of the members of the team. For example, with misalignment, the pump and its driver are not properly positioned relative to one another during operation. With foundation issues, the dynamic pump may not be adequately coupled back to the static earth, either through structural issues with the pump base (stiffness, for example), structural issues with the foundation (such as cracking or voids in the baseplate), or the joining of the two (for example, loose or insufficient bolting). And with piping, it is not safe to assume that a pipe flange magically connects to a pump flange with no effect whatsoever on the forces being applied to one another, particularly as thermal changes occur and the forces of the pumped fluid join the fray.

Properly diagnosing these pump-system vibration issues at the system level is often challenging because a) it can be technically difficult to know where to start looking within such a complex, interactive arrangement, and b) it can be organizationally difficult, both in terms of internal maintenance staff and external vendors, to sort out who is responsible to make things right. In terms of knowing where to start looking for the cause of the pump-vibration issue, sometimes there are "rule-outs" that can narrow the list of potential suspects, but it is often best to approach the situation with a curious, detective-like mindset, looking at the overall system's big picture and not ruling-out any prospective contributors prematurely. As for the organizational difficulties of sorting out responsibility, given the complexities of interaction, there is a contractual disincentive for vendors to take ownership of the problem. It is often going to be the de-facto responsibility of the end-user, or their appointed independent third party, to step back and look at how all the pump-system equipment is working together (or not working together as the case may be).

Current approaches

Historically, gaining a system-level diagnostic perspective for pump vibration problems has been possible, but it typically involves a lot of time and resources. Accelerometers

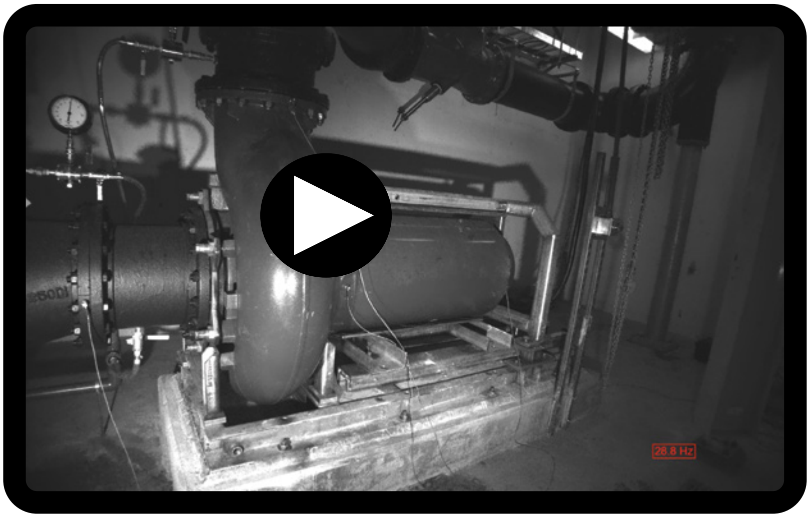


FIGURE 1. High-resolution video can capture a system-level matrix of vibration data in seconds

are temporarily roved throughout the pump system, similar to the way a physician would listen to various points of a patient's chest with a stethoscope. The vibration measurements obtained in this way are then mapped onto a wire-frame model of the pump system. The collated vibration data are subsequently synchronized and the motion exaggerated onto the model to visualize how the pump system's components are interacting with one another. This technique, aptly called "operating deflection shape" (ODS), can often identify the root-cause offender, because it translates point-specific vibration information into a contextualized shape of the deflection for interpreting the data.

While effective, this system-level technique requires both time and money — typically tens of thousands of dollars and days to weeks of data collection and post-processing time. Unless this is done frequently enough that maintenance personnel are able to keep sharp on the techniques involved, it is best left to external experts. The potential need for outside help turns every troubleshooting exercise into an explicit budgetary return-on-investment exercise as well, consequently leaving many chronic problems to fester below the investment threshold. Even if the problem "cost" passes the investment threshold, there is a persistent trade-off when collecting the data: since collecting data takes time (and therefore, the time equivalent of money), the pressure to get just enough data to make a diagnosis may not necessarily result in getting the data necessary to make the correct diagnosis.

Video vibration analysis

What if the same system-level analysis could be achieved simply by internal personnel with diagnostic information available in minutes instead of weeks, without the pressure of incremental data collection yielding an uncertain return on investment? Enter video vibration analysis, which uses high-speed, high-resolution video to capture a comprehensive, system-level matrix of vibration data in seconds, then post-processes that information in minutes, and presents accurate vibration information and motion-magnified video for system-level diagnostic evaluation (Figure 1).

These systems work by taking high-speed, high-resolution video, and then extracting vibration data based on the change in light intensity on a per-pixel basis. This change in light intensity at the pixel level is then referenced to real-world dimensions, and tiny amounts of motion are quantified as displacement data. The primary benefit of this technique is that these displacement data are comprehensive, capable of capturing the entire pumping system's vibration data simultaneously. As an added bonus in certain situations, it helps that it is a non-contact sensor, meaning that high temperatures and inaccessible equipment do not necessarily present a problem — as long as you can see it, you can measure it.

In addition to your data set, you now also have a picture of the system that you can enhance in various ways. Amplitude and phase data can be plotted onto the image to communicate location-specific data at the pixel level. And, the ultimate data enhancement is to take the actual motion that is present and magnify it, presenting a video with exaggerated motion of the entire system, similar to the ODS accelerometer-based approach, albeit without all the time-consuming hassle. Not only is this highly effective for root-cause diagnosis on system-level issues, it also becomes a very effective tool for not-quite-as-technical decision makers in the organization to understand what the problems and potential corrective actions are.

Factors to consider

On the surface, video vibration analysis sounds great, but a reasonable question to ask is "what's the catch?" Any new technology can be as useless as snake oil without understanding the fundamentals that will enable it to be successfully deployed to meet the expectations that you and your organization have for it. The following are several factors that have been found to be critical to ensuring productive and successful use of the technology.

Toy versus tool. Beware the "as-seen-on-TV" rush to get the latest diagnostic gadget, only to leave it on the shelf unused over time because of training or support issues. Video vibration analysis does indeed qualify as new technology, and does require personnel to acquire proficiency in some new skills and techniques. It is doubtful that most maintenance teams include professional videographers, so it is important to make sure to budget resources for training. A sufficient critical-mass of skilled and teachable users and internal customers will ensure that the new capability will be adopted by your organization.

In addition to standard software support, it is also important to consider "engineering support." Given the novelty of the technology, it helps to have mentors available to help determine the following: first, whether or not you have collected good data, and most importantly, what to do if you didn't; and second, how to in-

terpret the data for successful diagnosis and problem resolution. If your organization has experience collecting and interpreting ODS data, you have a head start, but this head start shouldn't be confused with the finish line. There is a lot to learn about how to best use this new technology, and in the words of American author and motivational speaker Zig Ziglar, "Some of us learn from other people's mistakes, and the rest of us have to be other people."

Capex versus service. Given its novelty, and the commitments required to truly make video vibration analysis technology successful in your organization, each company should evaluate whether it makes sense to acquire, staff and maintain the technology in-house, or if it is preferable to rely on third-party service providers. Sometimes organizations opt for an incremental approach, trialing video vibration analysis via a third party, before committing to purchasing the technology outright. If your organization does engage with third parties, either for evaluation purposes or for permanent supply of the capability as a service, do not assume that any organization with a high-speed camera and some software knows what they are doing. As discussed previously, this is a tool that requires training and experience to utilize properly, and if your organization prefers to outsource, make certain that the training and experience is indeed present in the third party. As an additional consideration, proficiency with a diagnostic tool does not automatically make one a skilled problem solver. In order to properly diagnose and solve problems using video vibration analysis, people are still required to understand and interpret the data, and conceive of solutions, so make sure you are hiring the right people, not just time with a widget.

If you do conclude the technology belongs in your organization, or even if you opt to rely on service providers, you will need to do some homework to understand the various capabilities available.

Detection threshold

One of the most important concepts, and possibly the least explained in the industry, is the detection threshold. Perhaps you have heard complaints about the technology not working except for very high vibration levels, or have experienced this issue yourself. This is likely due to the detection threshold. In short, video vibration analysis has a minimum level of displacement required before it can detect the signal (Figure 2).

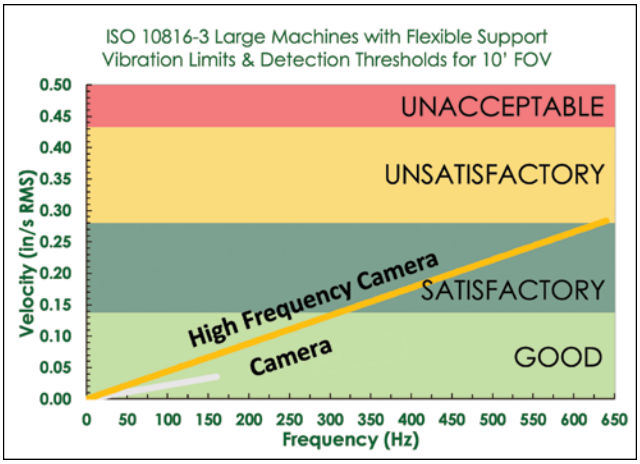


FIGURE 2. Any velocity values above the detection threshold lines will be accurately detected and magnified. Understanding the detection threshold as it relates to frequency is very important for diagnosing lower-displacement issues

Unlike the piezo-electric accelerometer, which can effectively measure nearly zero vibration, the pixel of the camera sensor has a noise baseline that makes a measurement of near-zero impractical (more on that later). Thus, is becomes critical to understand what that minimum level of displacement required is, and equally important, what the displacement depends on, because it's not absolute — it's relative.

Given that this is an optical measurement, and that a pixel has specific dimensions of its own, each pixel is subsequently covering a given amount of space on whatever the camera is viewing. As a basic example, consider a four-pixel camera (two pixels wide by two pixels high). If this four-pixel camera was observing a 1-in. × 1-in. square, then each pixel is observing a 0.5-in. × 0.5-in. area for motion, and its detection threshold scales accordingly for this area. Now if the same four-pixel camera then observed a 1-ft × 1-ft square, each pixel would then be observing a 6-in. × 6-in. area for motion, and the detection threshold would be scaled higher to accommodate the larger area. Since there are typically millions of pixels in play, the detection threshold is most effectively considered as a function of the pixels in aggregate, or the "field of view." Rather than determining what each pixel is measuring to figure out the detection threshold, their combined dimensions can be easily determined. For example, a 10-ft-wide field of view (meaning the camera is viewing something 10-ft wide from horizontal edge to edge) has a given detection threshold when considering all the horizontal pixels together (for example, 1,920 pixels wide). In this example, each pixel is observing a 0.0625-in. × 0.0625-in. square, with the detection threshold being a function of that area.

The detection threshold is considerably less than the pixel dimension, but is not zero. The technical reason this detection threshold exists is due to the noise in the sensor. Recall that the fundamental measurement is variation in light intensity. The noise in the sensor (one of the millions of camera light detectors) effectively produces a relatively constant baseline level of light intensity variation. Consequently, actual change in light intensity due to movement within the level of the noise floor is not distinguishable from the noise itself, and therefore is not accurately measurable, or magnifiable for visual motion interpretation.

Keep in mind that this detection threshold is a displacement value, not a direct velocity or acceleration measurement. While there is no frequency dependency to the displacement value, there is a practical frequency relationship. As the frequency of vibration increases, the velocity required to reach a given displacement also increases (as the frequency of oscillation increases, there is less time for the pump to move from point A to B). Typically, vibration velocity is the measurement of interest when determining machinery health, so a fixed-displacement "detection threshold" will equate to an increasing level of velocity "de-

tection threshold" as the frequency increases. When this concept is applied, as the frequency increases, displacement levels are lower for a given velocity, and it becomes all the more significant to understand the displacement-based detection threshold to ensure adequate measurement and magnification at higher frequencies.

If you have followed the logic thus far, you may be thinking, "why not just reduce the field of view to see lower levels of vibration, even at higher frequencies?" This is indeed possible, to the point of detecting nanometer levels of displacement, but there is a trade-off. As discussed earlier, the primary advantage of this technology is the comprehensive nature of the measurement, whereby the user gets to "see" and measure all the components of the system together at once. By narrowing the focus to achieve lower levels of displacement detection, the user has resorted back to a small measurement area, which behaves similarly to the accelerometer, and thus forfeits the underlying value of the technology.

With this fundamental understanding of detection threshold in hand, note that there are two types of data realized, and potentially two different detection thresholds. Depending on the vendor, the vibration measurement may or may not have a different threshold than the magnification threshold. It is important to do your homework, and ask for data to support the claims, since your mileage may vary if the quoted measurements are not provided in an appropriate context (for example, what is the field of view for a given detection threshold?).

Also, with regard to the magnified motion capability, there are differing approaches to enhance the signal, producing the magnified motion videos. The two major methods are optical flow and sub-pixel magnification. Primarily in an effort to speed up the processing of all the pixel-level data, optical flow takes the millions of pixels collected and averages them together into regions, and applies significant gain, along with interpolation across regions, to effectively recreate the wire-frame model of ODS. If the averaged region size is sufficiently small (and the user sufficiently patient), reasonable enhanced video results can be achieved, but the user must appreciate that the interpolation combined with noise can leave much to the imagination, and finer details can be lost in the process. An analogy would be drawing with a paint brush versus a mechanical pencil.

On the other hand, sub-pixel magnification maintains a pixel-level analysis to keep the hard-won resolution in the diagnostic assessment. This makes detecting issues requiring detail possible that might be missed or misrepresented by optical flow, such as foundation cracking, loose fasteners, piping supports, and similar issues, while still being able to magnify overall motion issues, such as misalignment, that may be also displayed with optical flow. The motion is much more precise than optical flow, and effective at lower levels of displacement.

Accuracy

Regarding the accuracy of the technology, if all you need is a single-point vibration measurement, it is still going to be faster, easier and more accurate to obtain that single point of data with an accelerometer for the foreseeable future. The advantage of using video for vibration measurement is the comprehensive nature of the measurement, effectively taking millions of measurements all at once. But how accurate are the vibration data that the video vibration analysis provides? Is it just a visualization tool, or can you measure the vibration as well?

With the above discussion of detection threshold in mind (since accuracy will not be applicable if the signal is below the noise floor), there are several practical elements to consider to improve the accuracy. Since the measurement is one of changing light intensity, it is important to make sure there is a "Goldilocks" level of light — not too bright, not too dark. Either end of the spectrum ends up clipping the vibration signal, resulting in inaccurate measurements. Relatedly, since the technology is looking for a change in light, contrast is required to make a measurement. Given a featureless, smooth, single-color surface, there will be no accurate measurement possible. In situations where targets can be applied to provide a point of contrast, the camera and software can accurately derive displacement measurements (Figure 3). Once there is sufficient lighting and contrast, it is still up to the user to provide a dimensional reference of some sort, either the distance between the camera and target, or a reference length within the image itself. Either way, the system needs a way to correlate the pixel size back to real-world size. Any lack of accuracy in this step will directly correspond to a lack of accuracy with the calculated measurement.

And again, any vendor claims should be substantiated with data to support them, and their relevance should be clearly understandable by the user. For example, if the system has a certain accuracy, but it is for 0.1 in. peak-to-peak of displacement motion with a 1-ft field of view, it is not very relevant to the real-world pumping system conditions for which the user will likely be seeking accurate data. Understanding the accuracy, particularly as the system approaches the noise floor, and over the entirety of the frequency span, will help ensure users know what to expect when deploying the technology.

Additional capabilities

In addition to magnifying the motion present as a result of operating

FIGURE 3. A moderate level of light and ligh-dark contrast are required for accurate displacement measurements

forces within the system, like that achieved in an Operating Deflection Shape, there is another critical diagnostic piece of information when dealing with pumping systems: At what frequency is the vibration occurring, and what are the natural frequencies? Every system has several inherent natural frequencies. When these natural frequencies are matched (or "excited") by a forcing frequency in the system, such as 1x operating speed, they resonate. This resonance automatically amplifies the vibration level, and generally makes for a very bad day. When your pumping system "sings" in this manner, it is not music to the ear, but rather a headache.

These natural frequencies can be detected by intentionally impacting the object and then measuring the frequencies at which it naturally vibrates. While often done with an accelerometer, or several if the shape of the motion is being characterized, this can now be achieved quickly and comprehensively using video. Since the vibration after impact is generally very short in duration, several impacts can be "averaged" together, which reduces the noise floor, thus lowering the detection threshold. This lower detection threshold makes natural-frequency characterization using video possible, even while equipment is operating.

In addition to natural frequency characterization, is it useful to analyze trends in low-level vibration over time to understand how the condition is changing. If the detection threshold is too high, then the user must wait until the vibration levels are problematic to the point of requiring action before employing the technology. But the aforementioned averaging capability can also be applied using a keyphasor or similar signal to trigger multiple videos for averaging. This reduces the noise floor, and lowers the detection threshold, so that vibration issues can be monitored and understood well before they require intervention.

This can be useful for early-stage diagnosis of impending problems that have a certain characteristic frequency, since the video pixel intensity variation detected in this manner can be analyzed by fast-Fourier transform (FFT), and then the vibration-versus-frequency spectrum at each pixel can be determined by the motion magnification system. Various vibration levels, or changes in those levels, at key frequencies, can be excellent telltales for machinery diagnosis and prognosis, as discussed in the ISO 13373 series of standards.

Video testing simplifies the measurement and visualization of vibration on pump systems, enabling rapid diagnosis of vibration issues. ■

Edited by Scott Jenkins

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Simultaneous Pump and System Sizing

Flow analysis can aid in simultaneously sizing pumps and associated piping systems. The concurrent sizing can reduce wasted energy and improve pump reliability

Ben Keiser
Applied Flow Technology Inc.

IN BRIEF

SIZING EXAMPLE

FLOW ANALYSIS

COST COMPARISON

In the chemical process industries (CPI), a variety of incredible process-simulation tools are available to provide greater efficiency and understanding to numerous chemical processes. Key process-stream parameters include flowrate, pressure, temperature and process media composition. From these inputs, an entire operation can be modeled. However, these important process inputs can be easily taken for granted.

Piping networks are the lifeline to plant process units. Their operation is just as critical as the process units themselves to ensure that the required flows, pressures, temperatures and compositions are delivered. Pumps, piping systems, and other components must be sized and selected properly. Like process simulation, flow-analysis software can greatly aid the pump- and pipe-sizing process.

There is a vast amount of literature available that discusses the procedure for sizing a pump [*1*]. The procedure is simple for systems that involve one, two, or maybe three flow paths, and many engineers share the experience of running through these calculations at one point or another. However, when dealing with much more complicated systems that involve several flow splits, loops, control features, multiple pumps in parallel, and so on, it is not an easy task. This is where flow-analysis software offers great utility — not only to size the pump itself, but to also to provide much more insight into system operation, where you can model different scenarios, as well as system operation and configuration changes.

Ref. 2 discusses how to improve pump system reliability through determining how to operate pumps closer to their best efficiency point (BEP). The focus of that article was on existing piping systems to improve system reliability.

This article examines the benefits of concurrently sizing the pumps and piping system together, instead of sizing pumps and piping individually. Sizing the piping system with the pumps will allow the selected pumps to fit the system application better, and thus prevent dramatically oversized pumps. When pump oversizing occurs, it is typically dealt with by using throttling valves, an approach that not only wastes a significant amount of energy (leading to high electricity costs), but also diminishes pump reliability. Sizing the pipes and pump together establishes a functional design that also saves a significant amount of money by finding a lower-cost solution for the system. This is especially true when sizing the system with consideration of the overall lifecycle cost.

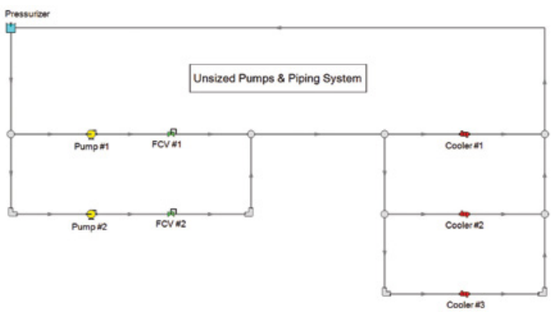

FIGURE 1. In the initial piping system layout shown here, pipe sizes and pump operating points have not yet been determined

Sizing example

Consider the system shown in Figure 1, where the pumps, piping, fittings and control valves need to be sized. For this system, there are four requirements that will dictate the piping size design. Fluid velocities inside the pipes must be below a certain threshold. There is a minimum pressure throughout the network that must be maintained. The coolers require a minimum flowrate for proper cooling. The pumps need to have plenty of margin between the net positive suction head available (NPSHA) for the pumps and the net positive suction head required (NPSHR) by the pumps.

To size the pumps, a desired flowrate will typically be specified in the model and the increase in pump head (or pressure) that is required to deliver the flow to overcome system resistance and elevation change will be determined. That es-

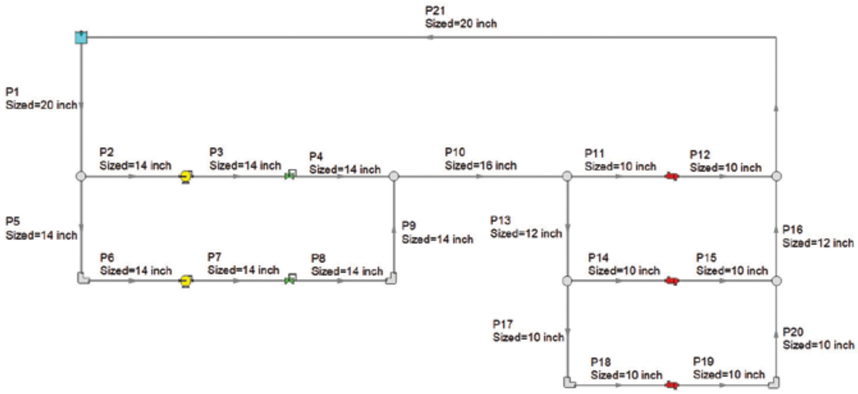

FIGURE 2. The pipe system shown here results when the design goal is minimizing initial system costs for material and installation

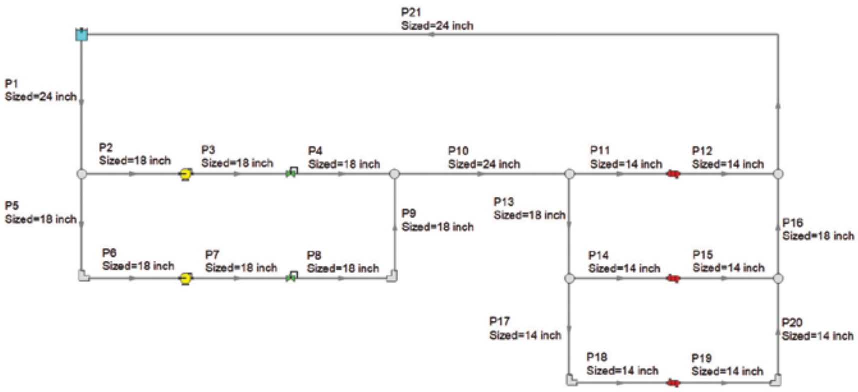

FIGURE 3. When the design goal is to minimize the lifecycle cost of the pipe system, the diagram here is the result. About 17% in cost savings can be realized compared to minimizing initial costs

tablishes the pump operating point, which can be used to select a pump.

At the same time, different pipe sizes throughout the system will be used to meet the design requirements. If any of the design requirements are not met, then those sizes would not yield a feasible design. As the pipe sizes change, the pump requirements for the desired flow will also continually change. Therefore, this is a highly iterative process.

Simply meeting the design requirements is not the only thing that should be considered in establishing a "good design." How can engineers know if it is good, or if the design could be better, or if it is the best possible design available? To answer this question, cost must be considered. Monetary cost for the system is certainly helpful in establishing a high-quality design. But at the very beginning of the design process, detailed costs may not yet be known. At that point, the overall piping weight can be a good initial start at the design.

Reducing piping weight typically corresponds well with reducing the initial material and installation costs for the system. Designing the pipe sizes with a maximum velocity requirement in mind can also help reduce energy costs in the long run.

Overall, the best design in theory would be the one with the lowest cost or lowest piping weight. It is worth noting that even when sizing the system based upon monetary costs, it is not necessary to have incredibly accurate cost data. Simple estimates, such as cost per length of piping or cost per power unit for pumps, is sufficient. Even if these costs are referenced from another project, industrial cost tables, old cost data, or even a guess, the "absolute" value of the cost is not what is important. What is important is the cost savings that is generated during the process of the system sizing.

Flow analysis

For the system being sized in Figure 1, the goal is to minimize cost for the appropriate sizes that will work. There are two different cost considerations to minimize: either the initial cost of the system or the lifecycle

DESIGN GOAL: MINIMIZE INITIAL COST

Costs (U.S. Dollars)	Material	Installation	Non-Recurring Sub Total	Energy	TOTAL
Total	$457,398	$293,404	$750,802	$3,293,986	$4,044,788
Piping	$388,405	$229,113	$617,518	$0	$617,518
Fittings	$37,955	$54,724	$92,679	$0	$92,679
Pumps	$31,038	$9,566	$40,604	$3,293,986	$3,334,590

DESIGN GOAL: MINIMIZE LIFE CYCLE COST

Costs (U.S. Dollars)	Material	Installation	Non-Recurring Sub Total	Energy	TOTAL
Total	$693,597	$372,831	$1,066,428	$2,276,293	$3,342,720
Piping	$613,327	$291,912	$905,239	$0	$905,239
Fittings	$59,961	$75,072	$135,033	$0	$135,033
Pumps	$20,309	$5,847	$26,155	$2,276,293	$2,302,448

TABLE 1. The costs of the sized piping system according to the different design goals are compared here

cost of the system. If we try to minimize the initial cost of the system, then smaller pipe diameters might be used, which would require larger pumps and higher power usage. In the long term, this will lead to higher energy costs. When attempting to minimize the overall lifecycle cost, then larger pipe diameters might be used to allow smaller pumps with lower power requirements from smaller pressure losses. This would lead to higher initial costs, but can save a sizable amount of money in the long run.

During the sizing process, many pipe size combinations will be used to try to meet requirements and decrease costs. Carrying this out manually is very difficult, but flow-analysis software with automated pipe-network sizing capabilities dramatically streamlines the process.

Imagine a situation where you were given ten different pipe-network size configuration options. You might start by trying a couple of the design options to see if they meet the design requirements. If one option did meet the requirements, how many more design options would you analyze to try to further minimize the costs? Most likely, many would be hard-pressed to analyze all ten options to find which one gave the lowest cost.

The reality is, there are not just ten different design options that exist, but potentially millions and billions. Flow-analysis software tools have sophisticated mathematical algorithms to quickly analyze a large number of different options. Engineers will have much greater ability to further investigate multiple options, leading to pathways that dramatically reduce costs while still meeting requirements.

In the simple system from Figure 1, there are a total of 21 pipes in the model. Pipe size is the independent variable that is being changed during the automated sizing process. Without grouping pipes together, there would be 21 independent variables and hence, there potential exists for 21 different pipe sizes. Since this number is not very practical, grouping various pipes together will help reduce the number of variables. This situation illustrates how there really are many different sizing combinations that can exist for a given pump-system design.

Cost comparison

After assuming basic material, installation and energy costs for the system, the model will result in two different pipe size designs. In one design, the goal is to minimize the initial cost for the system. Since energy costs can still easily be calculated, that information will be included for comparison. But this design will not consider energy costs for the sizing process. For the other design, minimizing the overall lifecycle cost (which does consider energy costs) will be analyzed.

Table 1 provides a comparison for the cost results for the sized piping system. The option to minimize the initial cost results in a total initial cost of $750,802. As seen in Figure 2, smaller pipe sizes are needed to meet the design requirements. However, calculating the energy costs of about $3.3 million will lead to a larger total lifecycle cost of just under $4.1 million over 20 years.

Considering pipe-size designs with the primary goal of minimizing the overall lifecycle cost will have a dramatic impact on long-term energy costs. This is because larger pipe sizes will be used and that reduces system pressure drop as well as pump-power requirements. Although the system shown in Figure 3 for the design goal of minimizing lifecycle costs results in about 42% higher initial costs, savings of 17% in total cost is realized in the long run. Notice that the energy costs for the case of minimizing lifecycle cost is about 31% lower than simply minimizing initial cost.

Lastly, now that the piping has been sized, the pump operating points are simultaneously determined. This allows the selection of pumps that will be a much better fit for the system demands, since the pump will not be unnecessarily oversized. They can also be selected to operate at close to their BEPs (or as close as possible) at the pump operating points.

Simultaneous pump- and pipe-system sizing will help establish a design that will meet the required flow, pressure, temperature and composition demands needed for various process operation. This allows engineers to have much greater certainty behind input values for their process simulation — now they are known instead of only being assumed. And if the pump-and-piping system is designed with the goal of minimizing overall lifecycle cost, this will have a dramatic impact in the long term. The approach will realize great monetary savings with reduced energy costs when compared to the approach of simply minimizing the initial cost of the system. Flow analysis can be accomplished with great efficiency using flow-analysis software with automated pipe-network sizing capabilities. ■

Edited by Scott Jenkins

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Scaling Up Hydrogenation Processes for Biomass Conversion

When scaling up new processes involving complex feedstocks, such as biomass, well-defined mixing is key. Guidelines presented here will help to efficiently move biomass hydrogenation reactions from the laboratory to commercial-scale operations

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Ekato RMT

IN BRIEF

- CHALLENGES AT LABORATORY SCALE
- PILOT TESTING
- CATALYST REUSABILITY STUDY
- HYDROGENATION REACTOR SCALEUP
- PROCESS PLANT ENGINEERING

One of the most promising pathways to biomass-based, sustainable chemicals is the sugar platform that includes conversions of monosaccharides, disaccharides and polysaccharides, and their derivates, via biochemical and thermochemical processes. Hydrogenation and hydrogenolysis reactions are of particular significance amongst those thermochemical pathways. Nature produces many different unsaturated products, including C=C double bonds, in carbonyl groups in the structural aldoses and ketoses of cellulose and hemicellulose. Hydrogenation is the key reaction to saturate those C=C and C=O bonds through the addition of molecular hydrogen, whereas hydrogenolysis describes a chemical conversion in which a carbon-carbon or carbon-heteroatom bond is broken by the insertion of hydrogen atoms. Both are similar in nature, as they are three-phase reactions with a liquid phase composed of the starting material (often solute in a solvent), hydrogen gas and a solid catalyst. These types of processes are best conducted in stirred reactors, where the liquid substrate is homogenized, the catalyst is suspended and the hydrogen is dispersed using a self-aspirating agitator in a compact and well-contained reactor system.

FIGURE 1. A 5-L pilot plant can be used to determine potential process limitations that are related to hydrogen-uptake rate measurement

However, the commercialization of such hydrogenation processes from the laboratory to production scale is traditionally complex and time-consuming. This is because the interaction between mass transfer, heat load, catalyst concentration and catalyst activity is intricate and requires an elaborate alignment between the reactor system and plant concept with the specific process requirements. Additionally, the substrates are refined from biomass and typically display varying compositions, even after refining, depending on the climate, harvest season and area of cultivation. This variation in chemical composition will impact selectivity and yield — unless the reactor system allows for sufficient process flexibility to adapt to changing substrate qualities.

This article describes a practical approach to respond to these challenges by applying an integrated development and optimization strategy beginning at laboratory scale, through piloting and demonstration scale, before building a commercial plant. Guidelines on how to approach specific hydrogenation problems, concepts and tools for the design, development and scaleup of catalytic hydrogenation processes are discussed.

Challenges at laboratory scale

The development of new chemical-production processes usually begins with conducting a basic experimental study of the chemical reaction, also called a feasibility study. If the process is a batch-wise, stirred process, then initial laboratory tests are often carried out in a reaction volume range between a few milliliters and a few hundred milliliters. At the laboratory scale, magnetic stirrers or very simple impellers are frequently used — however, these are often not appropriately dimensioned. This means that they are not representative of the process and therefore cannot be designed to be geometrically

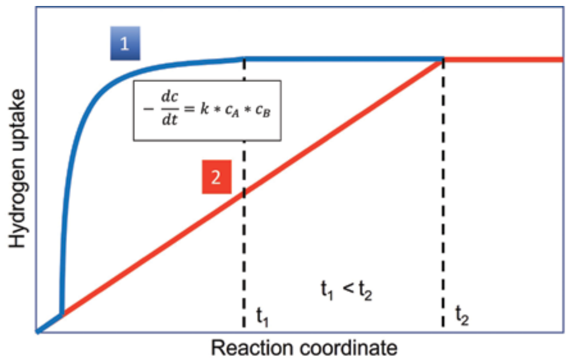

FIGURE 2. This reaction graph shows the hydrogen uptake rate in relation to the reaction time. The blue curve describes an ideal behavior (non-linear), and the red curve gives an example of a linear hydrogen uptake. The formula in the diagram gives an example of a typical second-order reaction

similar when moving the process to larger scales. Moreover, reactions are usually not conducted under well-defined mixing conditions. Often, laboratory reactors or other reaction vessels are not equipped with baffles, so the contribution of vortex gassing will be much higher compared to larger scales. Thus, it is recommended to follow up a successful feasibility study with pilot testing at the multi-liter scale, which is described in the next section using a 5-L pilot testing example (Figure 1).

Pilot testing

Frequent mistakes that are encountered at the milliliter scale, such as the incorrect assumption of the impeller flow regime or Reynolds number, which result in over-estimation of the viscosity, excessive volume-specific power inputs or not accounting for the importance of the ratio of vessel wall area to reactor volume, can be adjusted during pilot testing at the 5-L scale.

Hence, the key aim of pilot trials is to reproduce the results obtained under well-defined mixing conditions. Typically, only the process data collected under these conditions will provide useful information for a safe and reliable scaleup and de-risking. Moreover, pilot studies at the 5-L scale allow process-parameter optimizations, such as the improvement of the chemical conversion or fine-tuning of the selectivity.

A major challenge during the pilot trials is to identify possible limitations to the production scale in terms of mixing time, mass transfer and particle suspension. These limitations can then be considered in the agitator, reactor and plant design.

For this reason, it is advantageous to have the possibility of investigating chemical reactions starting from intermediate sizes of 5 L up to approximately 60 L.

A constant hydrogen uptake rate over the batch time clearly indicates that the hydrogenation is carried out in mass-transfer-limited conditions. Hence, it is advantageous that pilot reactors are equipped with mass-flow controllers for an accurate measurement of both the hydrogen uptake rate and the cumulative total hydrogen uptake. A linear hydrogen uptake usually shows that the reaction is limited when compared to the typical S-type behavior of a reaction (Figure 2).

In hydrogenation reactions, the limitations may be related to mass transfer — usually due to the transfer of the gas into the liquid. This means that the reaction is slowed down by an insufficient availability of hydrogen. If this is the case, the utilization of a self-inducing gassing turbine helps to overcome this problem by increasing the hydrogen availability via constant, secondary hydrogen-gas recirculation. Even with these modifications, reactions may still be limited, necessitating additional adjustments. Here, a possible solution can be found by increasing the volume-specific power input by the agitator. Another solution, which may favor the reaction rate, is to increase the hydrogen pressure. The best results can be obtained by increasing both parameters, but there are also reactions that do not respond to these modifications, since they are not limited by the availability of hydrogen.

If the hydrogen uptake rate remains linear, the reaction obviously was not limited by the availability of hydrogen, but possibly by a limitation in the total solid-liquid interfacial area of the catalyst in the reactor. This can be investigated in extended tests to see if the linear behavior can be improved by increased catalyst concentrations.

In summary, by observing the hydrogen uptake behavior, certain limitations related to mass transfer can be deduced. Based on the individual analysis of the source of the limitation, tailored solutions to best address these limitations can be developed.

Catalyst reusability study

Feedstocks derived from biomass may have more complex side-products and impurities when compared to traditional, industrially produced raw materials. Additionally, a feedstock's quality may vary due to natural fluctuations, requiring a more demanding process-control strategy and the need for a broader, more robust process window. Due to the presence of a potentially higher degree of catalyst poisons, the aspect of catalyst reusability becomes more important.

To determine the total cost of ownership, engineers should not only consider the costs for the raw materials, catalyst manufacturing and utilities — they should also evaluate catalyst reusability. The more cycles the catalyst can be reused until replacement with fresh catalyst, the more economical the entire process becomes. A determination of the possible number of catalyst reuses can be evaluated during pilot testing. One key piece of information derived from such a study is the evaluation of the number of reuses until the reaction time becomes too long due to catalyst deactivation. Here, “too

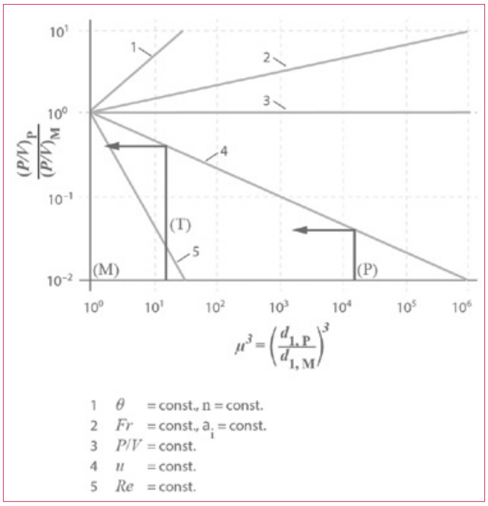

FIGURE 3. The Penney diagram is a useful tool for scaling up stirred reactors, wherein multiple process criterion can be visualized

EMPIRICAL CORRELATIONS FOR MIXING TASKS

1. $P = \mathrm{Ne}\rho n^3(d_2)^5$

2. $k_L a = c_1({}^{P}/_{V})^x(v_{sg})^y$

3. $\alpha = c({}^{\lambda}/_{d1})\mathrm{Re}^x\mathrm{Pr}^y(\eta/\eta_{wall})^z$

4. $n\theta_M = 5.5(d_2/d_1)^{-2}\mathrm{Ne}^{-1/3}$

5. Suspending criterion: $P_{Agitator} >>> P_{Settle}$

NOMENCLATURE

Variable	Unit	Description
c	-	Empirical constant
c_1	-	Empirical constant
d_1	m	Diameter of reactor
d_2	m	Diameter of impeller
$k_L a$	1/s	Mass-transfer coefficient
n	1/s	Stirring speed
P	W	Power input
P/V	W/m³	Specific power input
P_{Settle}	W	Suspension settling power
x	-	Empirical constant
y	-	Empirical constant
z	-	Empirical constant
α	W/m²·K	Heat-transfer coefficient
η	Pa·s	Dynamic viscosity
θ_M	s	Blending time
λ	W/(M·K)	Thermal conductivity
v_{sg}	m/s	Superficial gas velocity
ρ	kg/m³	Liquid density

long” means that the reactor cannot reach the required batch cycle time and production output. With this information in hand, the catalyst costs can be determined, allowing for a realistic estimation of the process economy and operational expenditures (OPEX).

Hydrogenation reactor scaleup

Scaling up results from laboratory or pilot-plant trials to the commercial scale can be a challenging task, especially for complex three-phase systems like the hydrogenation of plant-based materials. The relevant mixing tasks include gas-liquid mass transfer, heat transfer, suspending solid catalyst particles, recirculation of unreacted hydrogen back into the liquid and fast homogenization. In general, dimensionless numbers, such as the Reynolds number (Re), the Froud number (Fr), the Power number (Ne) and the Prandtl number (Pr), are used to describe and scaleup these mixing tasks. However, it is practically impossible to maintain all relevant parameters as constant while changing the scale. This behavior can be observed in the Penney diagram (Figure 3), where each straight line represents a scaling criterion. It shows the ratio between the specific power, P/V, at the production scale (P) and the model scale (M) as a function of the volumetric scale factor μ^3. The various straight lines (1–5) are obtained from a combination of the power equation with the respective scaleup criteria. Possible scaleup criteria shown in Figure 3’s example diagram are constant blend time θ (1), constant heat-transfer coefficient α_i (2), constant specific power input P/V (3), constant tip speed u for scaling up a suspending task (4) and a constant Reynolds number (5).

In practice, it is advantageous to have a heuristic procedure for the scaleup of hydrogenation reactors at hand, as illustrated in Figure 4. By following this procedure during process development, safe scaleup to commercial scale can be realized. First, (Step 1), trials should always be done with original material at real process conditions in order to observe possible non-ideal behavior and to gain knowledge about crucial process parameters. The trials should be done in a well defined reactor with a minimum size of 5 L. With that setup, the reactor and the related mixing tasks can be modeled using well-known correlations for power input, mass-transfer coefficients, heat-transfer coefficients and mixing time in a “digital twin” of the laboratory-scale reactor (Step 2). Without a validated set of empirical correlations (see Correlations box above) for the various mixing tasks, it is practically impossible to provide a safe scaleup of a stirred reactor. The empirical constants depend on the geometry of the reactor and impeller, respectively. Therefore, these empirical constants mostly result from know-how of the vendor

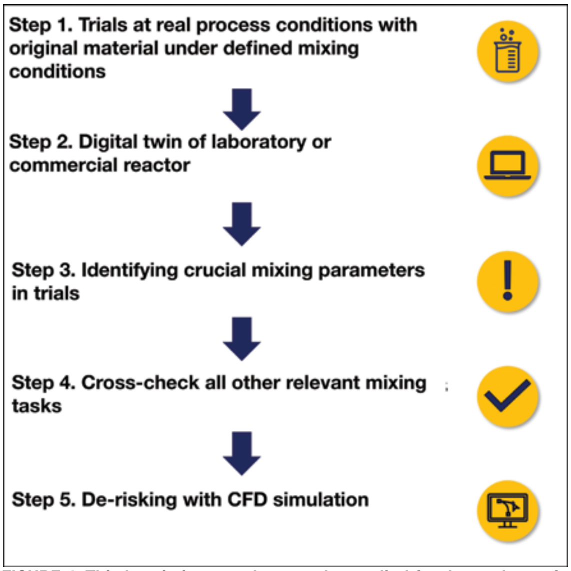

FIGURE 4. This heuristic procedure can be applied for the scaleup of hydrogenation reactors

for a specific impeller. At the same time, while modeling the laboratory reactor, a first design of the commercial reactor can be proposed and compared to the model of the laboratory-scale reactor.

During process development, it is essential to find the critical mixing task of the process (Step 3). This mixing task can then be used as the main scaleup criterion to commercial scale. Due to the relationship described in the Penney diagram, other relevant mixing tasks will change during scaleup. The commercial reactor design is then finalized by cross-checking all relevant mixing tasks (Step 4). In a last step, the scaleup can be verified using computational fluid dynamics (CFD) simulations (Step 5). This step is optional — but can be especially useful if complex requirements exist, such as a certain homogeneity in temperature or concentration distribution.

Process plant engineering

Having performed a successful study followed by an appropriate scaleup to the commercial scale, the centerpiece of the process — the hydrogenation reactor — is well-defined. Now, the task at hand is to design the industrial production process and the corresponding systems engineering. For the hydrogenation of biomass-based materials, single-source suppliers offer not only the reactor design, engineering services and construction of plants, but also support for commissioning. This integrated approach can result in a faster implementation. The engineering ideally is divided into three phases, as described in the following sections.

Phase 1: Concept study. Within the framework of concept studies, operating conditions, such as pressure and temperature, the type of catalyst and the dosing options are determined from the laboratory data. The upstream and downstream process steps, such as catalyst preparation and separation, are also considered in the concept study. Special attention is paid to the potential to reuse the catalyst. Catalyst handling is often underestimated and needs to be addressed accordingly. Depending on the concept, manual operations, as well as partially and fully automated systems, are possible options.

Phase 2: Basic engineering. During basic engineering, the dimensions of the main equipment components are determined. These are based on the general requirements of the end users, such as the desired production volume and the available media and energy sources. At the same time, the piping and instrumentation diagram (P&ID) is compiled during this stage of development. Transfers to storage tanks, devices for dosing and safety devices are also defined in the basic engineering. The P&ID is an important planning document for the further progress of the project. A reduced number of interfaces in this project phase leads to reduced planning and investment costs. During the basic engineering phase, it is usually necessary to initiate the procurement process for components with long delivery times, in order to be able to complete the system in a timely manner. As a result, this project phase is of the utmost importance.

Phase 3. Detailed engineering. In the subsequent detailed engineering, the P&IDs, pipelines, fittings, measuring points and control circuits are completed and finalized. At the same time, the piping layout and functional description of automation are created. Based on these documents, the procurement of the components and the assembly planning begins.

The combination of process development, engineering and construction and support for commissioning strongly reduces project times, which is essential in a growing field like the hydrogenation of biomass-based materials. ■

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New Applications for Spiral-Tube Heat Exchangers

A decades-old, yet less well-known type of heat exchanger offers advantages for new and emerging applications

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Spiral-tube or helically-coiled heat exchangers have been around for decades addressing sample cooling, mechanical seal cooling, vent condensers, vaporization and general heating or cooling requirements. They serve niche or unique applications and are not as well known or understood as are ubiquitous shell-and-tube or gasketed-plate heat exchangers. With turnover in engineering departments and entrance of younger engineers, a loss of familiarity with, or awareness of, spiral-tube heat exchangers is inevitable.

The last several years ushered in new heat-transfer requirements that fit spiral-tube heat exchangers perfectly. The energy transition, applications involving supercritical-fluid heat transfer [*1*] and a focus on removing or reclaiming volatile organic compound (VOC) emissions [*2*], to name a few drivers, have increased demand and expanded the applications where spiral-tube heat exchangers are used.

This article introduces — or for some, reintroduces — spiral-tube heat exchangers and provides an overview of new applications where they are being used or are specified for emerging or developing markets, such as the hydrogen economy, botanical extraction, compressed natural-gas systems, cryogenic vaporization and vent-emission reduction.

Spiral-tube heat exchanger

A spiral-tube heat exchanger consists of a number of tubes stacked and helically coiled (Figure 1). The coiled tubes at each end are welded, soldered or brazed into manifolds or piping that permit fluid to enter and exit the coil. In heat-exchanger parlance, this is referred to as the tube side of the heat exchanger. The coil is placed inside a casing or housing where a baseplate provides for a sealed enclosure, creating the shell side, or casing side, that permits fluid to enter and flow along a pathway exposed to the exterior of the coil and then exit the heat exchange area.

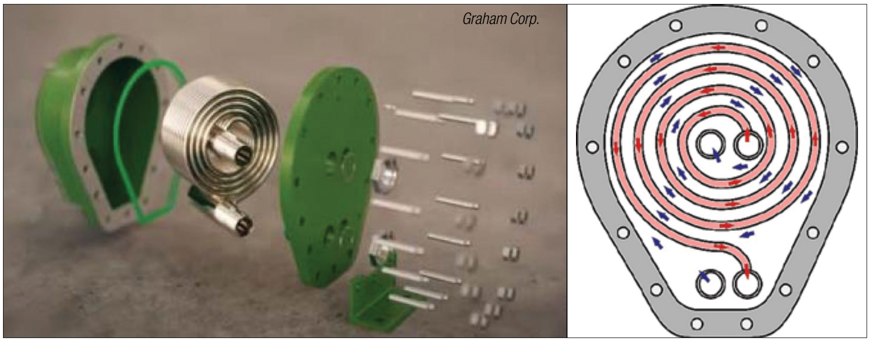

FIGURE 1. On the left is an exploded view of a spiral-tube heat exchanger. The flow path of the heat-transfer fluid is shown on the right

A number of advantages are present with such a configuration [*3*]:

Compactness. The straight length of tubing, which can be 45 ft long, is coiled, resulting in a smaller footprint as compared to a corresponding shell-and-tube heat exchanger. This attribute is ideal for heat-exchanger integration within a packaged system. For example, a spiral-tube heat exchanger with 380 ft^2 of heat-exchange area addressing a 3,000 psig operating pressure occupies a volume of 5 ft × 4 ft × 4 ft. In contrast, a shell-and-tube heat exchanger with high pressure on the tube side occupies a volume of 15 ft × 3 ft × 2 ft. The 15-ft tube length for a shell-and-tube exchanger causes integration complexity and an increase in floor space needed for the overall packaged system by approximately 10 ft.

High pressure capability. The coil is comprised of cylindrical parts, specifically, the tubes and manifolds, which can withstand high operating pressures. Pressures of 5,000 psi (345 bars) are rather routine, and for hydrogen service, pressures of 15,000 psi (1,000 bars) are economically possible. This attribute is an ideal fit for supercritical-fluid service, where operating pressure is high, or for hydrogen fueling systems.

Maximized LMTD. Fluid-flow orientation between hot-side and cold-side fluids is fully countercurrent, thus eliminating logarithmic mean-temperature difference (LMTD) correction factors for multipass shell-and-tube heat exchangers. Such an attribute is ideal when heat transfer requires a temperature cross, more specifically, when the hot side is cooled below the cold-side fluid-outlet temperature.

Large temperature differences. The coiled geometry permits handling large-temperature variation between the hot- and cold-side fluid. It is not uncommon to have a cryogenic temperature on the tube side, such as liquid nitrogen at –280°F, and steam on the casing side at 300°F. This coiled geometry characteristic is well suited when thermal growth issues are challenging in shell-and-tube type heat exchangers

Removable bundle. In most common geometries, the casing or shell side is accessible for cleaning or removal of fouling deposits. Also the coil can be removed and easily replaced.

Materials of construction (MoC). MoC for coiled-tube heat exchangers are comparable to those common for shell-and-tube exchangers, including stainless steel, duplex,

FIGURE 2. Three spiral-tube heat exchangers are shown here (arrows) within a Neuman & Esser hydrogen diaphragm-compressor package

copper, copper-nickel, titanium, Hastelloy, Inconel and Incoloy. The casings are commonly in cast iron, cast steel, fabricated steel or stainless steel. Although any material that can be cold worked (rolled) and welded may be used for the casing or shell side.

High-pressure applications

When fluid operating pressure is elevated, above 750 psig, as an example, a spiral-tube heat exchanger is an ideal candidate. New energy applications, such as hydrogen-fueling systems or remote natural-gas delivery systems, create new demand for this type of heat exchanger. Similarly, developing markets, such as supercritical CO_2 for botanical extraction or shelf-stable alternatives to traditionally frozen foods and also mature markets for industrial gases, like helium systems, also require these specialized heat exchangers.

Hydrogen fueling systems. The energy transition and search for nonfossil-based transportation fuels has brought hydrogen to the forefront as a fuel for fuel-cell electric vehicles. The Society of Automotive Engineers Standard SAE J2601 governs fuel-station requirements for light duty vehicles and buses. Dispensing pressure to the vehicle is either 10,000 psi (70 MPa) or 5,000 psi (35 MPa). These are extremely high pressures. Diaphragm compressors are used to increase hydrogen pressure to the required storage pressure. The compressors are multi-stage, where heat exchangers remove heat of compression (Figure 2). Spiral-tube heat exchangers are used for compressor inter- and after-coolers to remove heat caused by compression. At such high operating pressures and for system integration, spiral tube exchangers are chosen. A typical heat removal requirement for a hydrogen compressor inter-stage cooler is 100 lb/h of hydrogen at supercritical pressure of 2,000 psig cooled from 300°F to 100°F. For the final compression stage the heat removal requirement typically is the same 100 lb/h of supercritical hydrogen at 10,000 psig cooled from 250°F to 100°F. Actual mass flowrate will vary from installation to installation as will the inter-stage and final-stage cooling requirement based upon compressor design.

Another use of spiral-tube heat exchangers in hydrogen fueling stations is for precooling the hydrogen before it is dispensed to a vehicle. SAE J2601 refers to T40 or T30, for example, meaning the dispensing system is to deliver hydrogen to the vehicle at –40°C or –30°C, respectively. The temperature is essential for meeting fueling time requirements.

Hydrogen has a unique thermodynamic property that is unlike most other gases, except for helium. Most gases, when passing through a control valve, expand adiabatically to a lower pressure and experience a reduction in temperature. Due to a negative Joule-Thomson coefficient for hydrogen and the operating conditions of the fueling system, when hydrogen flows through a flow control valve and undergoes a pressure loss, the temperature actually rises. If the resultant rise in temperature isn't removed, it affects the vehicle filling time.

A hydrogen precooler is used to remove the heat caused by pressure drop across a flow-control valve in the supply line to the fuel dispenser admitting hydrogen into a vehicle. Here too, pressure is high and in the range of 10,000 psi for automobiles or 5,000 psi for mass-transportation vehicles. The removal requirement is typically 120°F hydrogen cooled to –40°F (–40°C) for a J2601 T40 fueling system.

Developing heat exchanger designs at pressures of 5,000 psi or greater with hydrogen in supercritical state is not ordinary fare.

Botanicals, shelf-stable foods

Supercritical CO_2, where pressure is above 1,075 psia and temperature in excess of 88°F, serves as an ideal solvent for separating essential oils by varying CO_2 pressure and temperature. To effect precise control of the extraction or separation process, a heat exchanger is used to heat supercritical CO_2 at pressures in the range of 4,000 to 5,000 psig from approximately 32°F to 140°F. Tailoring the solvating properties of supercritical CO_2 is important for separating high-purity plant oils. Spiral-tube heat exchangers handle the high-pressure service economically, provide reliable outlet temperatures and integrate into an extraction system package compactly (Figure 3). Also to bring CO_2 to the 4,000 to 5,000 psig operating pressure diaphragm or reciprocating compressors are utilized. Inter-stage and final-stage compressor coolers apply spiral-tube heat exchangers where heat of compression is removed.

An emerging market involves the

FIGURE 3. A spiral-tube heat exchanger (blue) is integrated into Advance Extraction Systems' supercritical CO_2 botanical extraction system

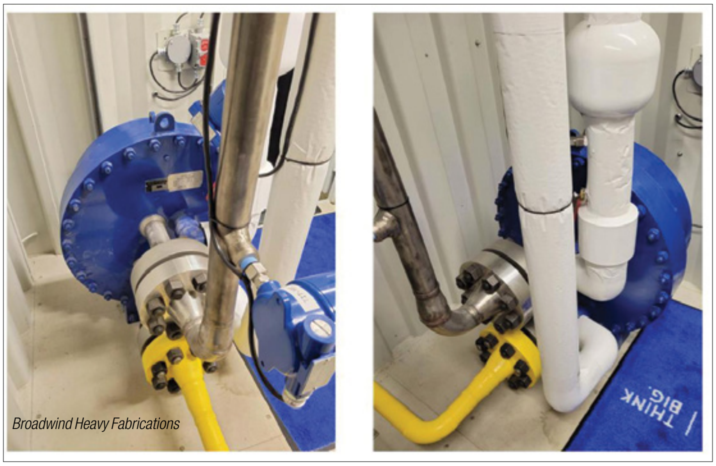

FIGURE 4. Spiral-tube heat exchangers within a Broadwind Heavy Fabrications compressed natural-gas pressure-reduction system

use of supercritical CO_2 to produce quality food products that do not require freezing, refrigeration or cold storage. Supercritical CO_2 is used to sterilize foods that are shelf-stable, thereby eliminating requirements for cold-storage infrastructure, such as refrigerated tractor trailers, cold-storage warehousing or grocery store refrigerated-food displays. In this application, CO_2 is compressed to 4,000 to 5,000 psig and spiral-tube heat exchangers are applied to remove heat of compression.

Compressed natural gas systems

In remote locations, where infrastructure and pipeline-delivery systems for natural gas do not exist, compressed natural gas is trailered to the location. Natural gas with pressures in the range of 4,000 psig is delivered in truck trailers. Then pressure-reducing systems lower the natural-gas operating pressure for use by a remote user. Spiral-tube heat exchangers are applied to heat the high-pressure natural gas prior to pressure reduction to maintain acceptable operating temperatures following adiabatic expansion across the pressure-reducing system. As described previously, this typically results in cooling of the natural gas. For example, Permian Basin hydraulic-fracturing sites can improve drilling rig economics by using dual-fuel engines that can operate with diesel or a diesel and natural-gas mixture. During times of high diesel fuel prices, diesel/natural-gas mixture dual-fuel, where natural gas displaces 60–70% of the diesel, greatly improves drilling rig operating cost. Fracking sites often do not have natural-gas distribution systems, thus "virtual pipelines" are employed, where compressed natural gas at high pressure is trucked to a remote location where decompression systems lower the pressure for use in an industrial application (Figure 4), such as a dual-fuel engine. Additionally, this type of "virtual pipeline" may be used as a fuel source for peak shaving on limited pipeline capacity and pipeline outages or for another industrial application where natural-gas pipeline infrastructure is not present.

Likewise, spiral-tube heat exchangers are used on the compression side of the natural gas value chain. In the Marcellus Shale Play, natural gas is co-produced along with shale oil during the hydraulic fracturing process. Natural gas can be compressed to 4,000 to 5,000 psig for use in compressed natural gas fueling stations, where trailer trucks are filled with the high-pressure natural gas. When the gas is compressed, the heat of compression must be removed. Spiral-tube heat exchangers are applied as compressor inter-stage and after-coolers to lower the temperature of the 4,000–5,000 psig gas subsequent to compression.

VOC or product recovery

Reducing harmful or valuable emissions from chemicals processes is always a top priority for environmental stewardship and to improve unit economics. Owing to compactness and effectiveness of condensation with minimal pressure loss, spiral-tube heat exchangers can be considered. Spiral-tube exchangers have three common configurations for vent or process condensing (Figure 5). A low-cost option is where the coil or bundle fits inside the process vessel such that process vapors and gases flow around the outside of the coil and condensable vapors are condensed for reflux back into the vessel. A similar, but more expensive option is where the condenser is mounted on a vessel discharge flange. In this case, process vapors and gases flow around the outside of the coil condensing condensable vapors. In either case, the coolant flows inside the tubes. A desirable aspect of these types of condensers is that they mount directly onto a process vessel to avoid piping and associated hydraulic losses.

Figure 6 shows a cryogenically cooled storage-tank-vent condenser installed to eliminate 98% of methylene chloride (CH_2Cl_2) vapors vented or released from the storage tank

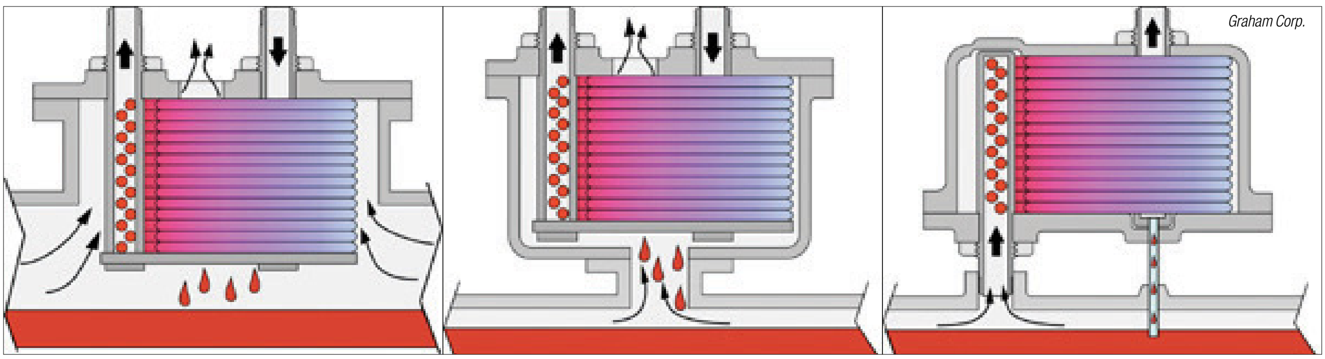

FIGURE 5. Spiral-tube heat exchangers can help lower environmental impact with VOC or product recovery. Three different configurations are shown here

FIGURE 6. Shown here is a cryogenically cooled storage-tank-vent condenser, which prevents the release of vapors into the atmosphere

during filling operations or as a result of changes in ambient temperature leading to release of CH_2Cl_2 as the storage tank breathes. In order to meet the high reclamation rate of 98% recovery of CH_2Cl_2, liquid nitrogen at –275°F is used as the coolant in order to cool vent vapors to –60°F. Such cold temperatures provided the desired elimination of CH_2Cl_2 from the vent while not freezing the vapors onto the tubing. Due to the importance of eliminating the majority of the vented vapors performance of the vent condenser was verified using U.S. Environmental Protection Agency Method 25A "Determination of Total Gaseous Organic Concentrations using a Flame Ionization Analyzer". It was confirmed that, during tank-filling operations where the venting is at its greatest, the spiral-tube vent condenser recovered 98.8% of the CH_2Cl_2 by cooling the vent stream to –65°F.

Another variation, often considered for corrosive process vapors or where miscibility of condensates is an important design element, is for condensation to occur within the tubes while a coolant is on the shell side.

Vent or reflux spiral-tube condensers use coolants such as liquid nitrogen, chilled methanol, ethylene glycols, brine solutions or low-temperature heat-transfer fluids. The temperature of the coolant is often dependent upon the process vapors, the amount of non-condensable gases and the targeted emission level of process vapors.

Large temperature gradients

Industrial gas applications involving vaporization of cryogenic nitrogen, oxygen or helium, for example, involve large temperature rises on the cryogen side that is flowing within the tube, and also substantial temperature differences between the hot-side fluid and the cryogen [*4*].

The coil-tube-bundle configuration is well suited for large temperature variation and thermal gradients that present mechanical design challenges for shell-and-tube heat exchangers due to thermal expansion. For example, in a lyophilization application (Figure 7), liquid nitrogen at –295°F and 100 psia is sensibly heated to –282.7°F, at which point the nitrogen isothermally absorbs heat and liquid changes state to vapor. After changing phases, the gaseous N_2 is warmed further to –120°F. The Syltherm XLT is cooled to –90°F and returned to freeze dryer for low temperature dehydration of a pharmaceutical.

In this application, another feature of spiral-tube heat exchangers stands out. Processing of pharmaceuticals is expensive and costly if a batch is subjected to poor temperature control, thus resulting in that batch being discarded due to poor quality. The lyophilization process takes place at low temperatures to permit sublimation of moisture from the pharmaceutical product. With liquid nitrogen as a coolant and a low-temperature heat-transfer fluid as the control fluid for the batch freeze-drying (lyophilization) process, tube wall temperature can be below the freeze point of a heat transfer fluid. Once a heat-transfer fluid begins to freeze, temperature control is lost and pharmaceutical product quality suffers as a result. The curved flow path of a spiral tube heat exchanger induces turbulence and mixing of the boundary layer at the cold tube wall. This turbulence and mixing aids in the mitigation of ice formation or runaway freeze-up, where temperature control is lost. ■

Edited by Gerald Ondrey

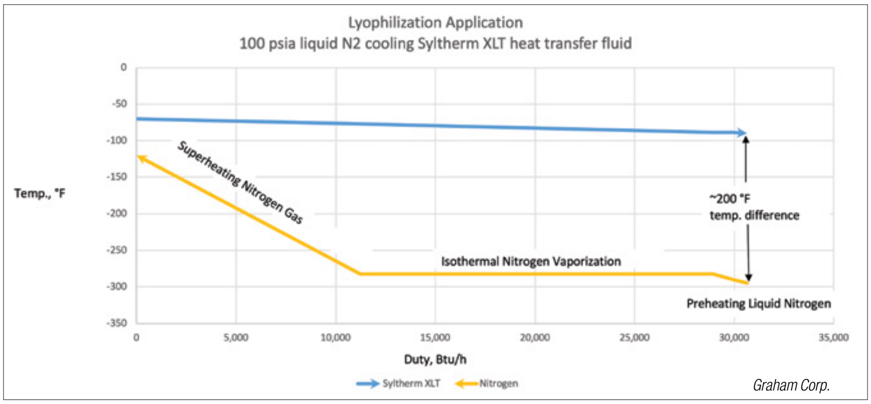

Figure 7. Shown here is the temperature-duty graph of a lyophilization application

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James R. Lines retired from Graham Corp. (20 Florence Ave., Batavia, N.Y. 14020; Phone: 585-343-2216; Fax: 585-343-1097; Email: jlines@graham-mfg.com) in 2021 following 37 years of service. He worked in various capacities in engineering, sales and general management for the company, and continues to provide engineering and management advisory service. Lines holds a B.S. in aerospace engineering from the State University of New York at Buffalo.

Driving Decarbonization at BASF's Schwarzheide Production Site

At brownfield operating sites, energy-efficiency gains can be realized by modernizing power-generation equipment. Ideally, such projects can take place without fully shutting off power or halting plant operations

Bernd Kuenstler
Siemens Energy

Over the last two years, virtually every major chemical producer across the globe has established targets for carbon-emissions reductions, with several companies making formal commitments to be 'net-zero' by 2050. However, achieving this feat will be no easy task. Power generation and heat production are typically among the largest sources of emissions for facilities that do not utilize grid electricity. This is particularly the case for sites with power or cogeneration plants commissioned decades ago.

With pressure on the companies that operate these facilities to become more sustainable, modernizing power plants via brownfield engine-exchange projects (such as replacing old equipment) has become an attractive pathway for decarbonization.

In recent years, Siemens Energy AG (Munich, Germany; www.siemens-energy.com) has been engaged by several of its industrial customers to perform brownfield exchanges of critical machinery, including gas and steam turbines and generators. One notable project began in 2019 when the company entered into an agreement with the world's largest chemical producer, BASF SE (Ludwigshafen, Germany; www.basf.com), to modernize a combined-cycle power plant at the Schwarzheide production site in eastern Germany (Figure 1).

The project concluded earlier this year. Among the many positive outcomes for BASF were a 4% increase in the overall efficiency of the power plant and a 16% reduction in greenhouse gas (GHG) emissions.

Site overview

Built in 1935, the Schwarzheide site has a long and storied history. BASF has retained ownership over the site since 1990, and aims for it to be one of the company's first locations to achieve carbon neutrality.

A broad range of products are produced at Schwarzheide, including performance chemicals, fungicides, foams, polyurethanes, engineered plastics, coatings and more. In the coming months, BASF also expects to start up a prodeuction facility dedicated to sustainable battery-cathode materials.

FIGURE 1. BASF modernized the power plant at its production site in Schwarzheide, Germany, which is now notably more efficient

The increased power demand that will be required at the site when the new facility is operational was one of the primary motivations behind the brownfield engine-exchange project.

Since 1994, power, process steam and heat demands for the production site have been met with a gas-fired combined-cycle power plant. Although the plant had generally performed well, BASF knew that an upgrade was needed to meet its ambitious sustainability targets.

To this end, the goal of the modernization project was to reduce overall emissions from the power plant and enable BASF to expand its onsite production capacities sustainably. Another objective was to provide the basis for integrating renewable energies in the near-term future.

In addition to realizing ecologically efficient power-plant technology at the site, the Schwarzheide team also wants the site to become more flexible, so they are balancing out the fluctuation of renewables they plan to integrate within their production processes in the coming years.

Brownfield engine exchange

Siemens Energy's modernization approach involved upgrading the power-generation equipment on one of the main power lines at the site by swapping out the old gas turbine from another original equipment manufacturer (OEM) with a more fuel-efficient unit — in this case, a new SGT-800 industrial gas turbine. The second power line at the plant remained operational so that chemical production could continue uninterrupted. As many project personnel described, the task was akin to performing "open-heart surgery."

Replacing the existing gas turbine with the SGT-800 would significantly reduce the fuel consumption and CO_2 emissions of the combined-cycle plant. However, as is often the nature of brownfield projects, the

FIGURE 2. A battery storage system ensured black start capability of BASF's power plant, meaning that site power was restored without relying on external power networks

engine exchange at Schwarzheide presented many unique challenges for the project team, including working in close quarters. Any vibration during assembly or installation of the SGT-800 turbine could cause a shutdown of the second running gas turbine, thus disrupting energy supply to the plant and impacting production.

A critical feature of the SGT-800 engine is its dry low-emissions (DLE) combustion system, which is capable of burning a wide range of liquid and gas fuels, including those with a high content of inert gases and heavy hydrocarbons, including diesel. The engine can also handle fuels that contain up to 75% hydrogen by volume. The combustor and burner designs offer single-digit CO emission levels and emissions from oxides of nitrogen (NOx) ranging from 9–15 parts per million (ppm) over a wide range of operating parameters.

Swapping out the old gas turbine with the SGT-800 enabled BASF to increase the power line's output by more than 15% — from 40 MW to 52 MW. The existing generator in the plant was also refurbished. This consisted of revamping the direction of rotation, optimizing the flow-side inlet channels in the rotor winding and modifying the base frame.

Together, the combination of the new gas turbine and refurbished generator, along with several other facility upgrades, resulted in a 4% increase in the efficiency of the power plant, translating into lower fuel costs per kilowatt-hour and a reduction in total GHG emissions of around 16%.

Additionally, a battery energy-storage system was installed for emergency power supply (Figure 2). The battery enables the black start of the power plant without relying on external power sources. At most power plants, this is typically done using diesel generators. The battery system has the power and capacity to provide three sequential black starts of the newly installed SGT-800 gas turbine without recharging.

Siemens Energy is also supporting proactive risk management for the gas turbine, including remote monitoring and degradation forecasting. In addition, where necessary, augmented reality (AR) tools will be utilized so that equipment experts can remotely guide BASF maintenance staff in isolating and troubleshooting potential problems. In this way, plant personnel will have critical information available remotely without Siemens Energy personnel having to be physically onsite.

Embracing partnerships

Even with a new gas turbine, refurbished generator and modifications made to the power plant at the Schwarzheide production site, the brownfield exchange was completed with a much lower capital investment than would have been required if BASF had elected for a complete power plant rebuild (greenfield project).

The close cooperation between Siemens Energy and BASF played a critical role in smooth execution. Each company was very transparent throughout the process and duly included each other to help manage risks. Because of this, the project was a success, and should serve as a model in what is possible when there is a clear vision for decarbonization and extensive co-creation between a chemical plant operator and a power plant OEM. ■

Edited by Mary Page Bailey

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Bernd Kuenstler (Email: bernd.kuenstler@siemens-energy.com) joined Siemens in 2009 as part of Siemens Turbomachinery Equipment GmbH in Frankenthal, Germany. In 2010, he joined the regional sales department of the Industrial Application Service and since then has worked closely with many customers in the greater Rhineland-Palatinate, Saarland and Hesse regions from Mannheim and Mainz. In 2016, he became part of the Siemens Account Management team for BASF and assumed the key account manager role for BASF when Siemens Energy was founded in 2020.

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120th Anniversary

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"Notwithstanding the great proportions which the applications of electrochemistry have assumed in the United States, and the valuable contributions which here have been made to the science and to the art, this vigorous and rapidly expanding branch of national industry has this far lacked a journalistic exponent. That a field exists in this country for a journal devoted specifically to the science and application of electrochemistry appears to be clearly indicated . . ." (from *Electrochemical Industry*, September 1, 1902).

Since then, the magazine has evolved along with the advancing fields of electrochemistry, metallurgy and others to what, since 1946, has been called *Chemical Engineering* (For more on the magazine's history, see "120 years and going strong," p. 4).

There have been enormous contributions and advances from chemical engineers over the past 120 years. And while the basic tenets of chemical engineering, such as heat and mass balances, remain the same, fast-paced technological advances, particularly in recent years, have supplied our industries with tools for seemingly unbounded progress. I expect that some of our readers today remember their first handheld calculator, perhaps even a slide rule, and who are now working with virtual reality and beyond. We look forward to continuing to bring information to the chemical engineering community, and are excited to see what the future holds.

Dorothy Lozowski

Inside

Meet the latest innovation in radar level sensors.

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INDECK

Indeck is a boiler OEM with roots tracing back to 1840 when it began production of high-quality boilers. Indeck has previously manufactured boilers under the names of Erie City Iron Works, Zurn Energy Division, Aalborg (land-based boilers), International Boiler Works, and Volcano.

Indeck was the first company to offer skid mounted and trailer mounted mobile rental boilers and has grown to have the world's largest boiler inventory. Indeck offers a variety of purchasing options: rent, lease-to-own, or purchase.

Indeck supports the following industries: petrochemicals, refineries, combined heat and power, cogeneration, pulp and paper, universities, airports, and food processing as a single source supplier offering the following:

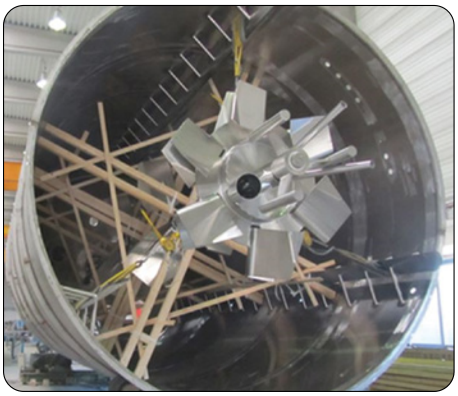
· Rental boilers and auxiliary equipment

- Stock boilers for immediate shipment
- Build to order boilers (A, O, D, and Suspension Truck D)
- HRSG (heat recover steam generators) and waste heat boilers
- FCC (fluid catalytic cracking) waste heat boilers
- International Lamont High Temperature Hot Water Generators
- Combustion controls, burner management systems, and fuel trains
- Solid fuel boilers and Travagrate stokers (wood, coal, municipal solid waste, and tires)
- Aftermarket services (re-tubes, burner retrofits, upgrades, parts, engineering studies)
- Field services: Installation, operator training, startup, testing

www.indeck.com

Mixing solutions for bio-based polymers

If plastics are produced on a regenerative basis, the climate and environmental balance is significantly better in addition to independence from fossil products. For the production of bio-based polymers, the biorefinery is developing as an alternative to the classic petrochemical processes. Away from sugar as the starting point, more modern processes aim to utilize almost all components of renewable raw materials.



EKATO large fermenter for the production of bio-based polymers (Photo: Ziemex)

Aerobic fermentation plays an important role in the production of bio-based platform chemicals or monomers. The agitated large fermenter is a highly efficient process solution, especially with regard to mass transfer, heat transfer and the yield and product quality that can be achieved as a result. Subsequent to the production of these bio-based monomers, they are purified, which often takes place in a crystallization step. At the end there is the polymerization or polycondensation to the bio-based polymer.

For all these different process steps, EKATO not only offers the right agitators, but also supports both the process development of the individual production phases and the engineering of complete agitator reactor systems. Processes with different starting products can be tested and optimized under realistic conditions in the EKATO R&D center or in tailor-made pilot systems. Based on the findings from pilot tests, EKATO develops complete reactor systems that are tailored to the respective needs of the customer.

- Analysis of process requirements
- Customized reactor concepts
- EKATO PHASEJET & COMBIJET for efficient gas dispersion
- CFD & FEM expertise
- Reliable scale-up to production size
- Joint development agreements for new processes

www.ekato.com

From backroom operation to global player

It was an unlikely pair that came together in 1953 to create a company: 29-year-old Swiss engineer Georg H Endress and 58-year-old German banker Ludwig Hauser. Despite their disparate backgrounds, it turned out they were a perfect match. Endress's vision and drive and Hauser's prudence and experience proved to be the cornerstones of the company's success.

Opening new markets step by step

The young company began its activities with the sale of innovative electronic level sensors that filled a market niche. It wasn't long before Endress began to develop instruments on his own. In 1955 he registered his first patent. In 1957 the company began trading under the name Endress+Hauser – and experienced strong growth. Georg H Endress continuously expanded the portfolio by adding new measurement principles and pursued business opportunities in other countries.

Customer intimacy from the very start

The company expanded its offerings through acquisitions and start-ups. Measurement value recording, liquid analysis and flow measurement engineering were added as new fields of activity to the mix, followed later by pressure and temperature measurement technologies. Endress+Hauser evolved into a full-range provider for the process industries.

The Endress family became the sole shareholder in 1975. Klaus Endress took over the reins of the Group from his father in 1995. Over the following years he expanded the business beyond process instrumentation and into services and automation solutions. He also tackled the challenges of doing business in a globalized environment. After establishing sales centers around the world, production also went global.

Family continues to shape the company

For 19 years Klaus Endress put his personal stamp not only on the Group, but also on the corporate culture. Most of all he valued communication and cooperation. Trust and loyalty supplement the deeply ingrained sense of responsibility within the company. The customers and their needs remain at the heart of the business, as well as the guiding principle 'first serve, then earn.' As Klaus Endress puts it, profit is not the target, but the result of doing well. The shareholder family created a family charter while Dr Georg H Endress was still alive. It states: Endress+Hauser shall remain a family company oriented toward sustainable success. After the death of the company founder in 2008, this statement became his corporate legacy. Klaus Endress handed over leadership of the company to Matthias Altendorf in 2014. The Group had already acquired laboratory instrumentation specialist Analytik Jena and further strengthened the segments of process analysis and measurement of quality parameters through additional acquisitions. Besides this strategic focal point, the issue of digitalization is another major factor driving the company forward. New technologies and business models place further demands on the Group while simultaneously creating opportunities for the future.

Three generations: The Endress shareholder family in May 2019.

www.endress.com/chemical

The Exotherm UNIFLUX high performance convective heater is the heater to use when your fluid matters! Our design will not damage your fluids, so you keep making money instead of making repairs.

- The UNIFLUX heater creates flue gas recirculation using a high velocity burner technology and a loose-wound process coil design.
- Completely combusted flue gas recirculates 8-10 times in the main heat transfer cabin, cooling before it reaches the process coil.
- The process coil never sees flame temperatures, providing a uniform and predictable flux rate.
- This design eliminates hot spots that could damage the fluid or the coil.
- The UNIFLUX heater allows fluids to be pushed to the design limits without degradation.
- The high velocity burner and unique coil design does it all!
- No High temperature fan to maintain.
- Single and multiple burner designs available.

Exotherm Corporation also manufactures Forced Draft Water Bath Heaters, Q-Pak Direct Fired Air Heaters, Heat Transfer Circulation Systems, and other Custom Designed Process Heaters. Contact Exotherm Corporation today and let us show you the UNIFLUX Advantage!

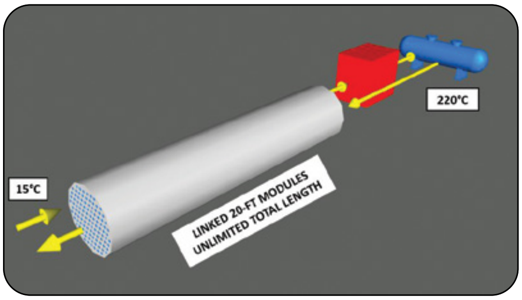
Exotherm Corporation

65 years of convective heat.

www.exotherm.com

A NEW TYPE OF HEAT EXCHANGER

Kappes, Cassiday & Associates, (KCA), has developed the Tube-to-Tube Heat Exchanger. It allows true countercurrent heat recovery and transfer from course mineral slurries and lumpy food-industry slurries such as soups. With this new technology, the hot slurry simply flows in pipes countercurrent to the cold slurry in adjacent pipes. This tube-to-tube exchanger promises to reduce the cost of a large autoclave system by a few hundred million dollars, while at the same time reducing the carbon footprint. It has been designed to handle easily-settling, abrasive mineral slurries. This technology has broader applications other than mineral processing. Food processors and chemical manufacturers often transfer heated, lumpy liquids. These liquids will flow evenly and transfer heat evenly in both directions through this new heat exchanger, and since the liquids are contained within the tubes, the unit is easy to clean and sterilize. Visit us at **www.kcareno.com**



Rota-Cone® Blender

The **Paul O. Abbe** Rota-Cone® blender is the ideal choice for thorough and gentle blending of powders or crystalline products. Because this tumble blender has no shaft seals or agitator, cleaning is simplified and cross-contamination minimized. All internal surfaces the Rota-Cone® can be inspected from the single loading hatch. Liquids can be added through the optional spray line and a pin agitator can be added to facilitate liquid dispersion, granulation or de-agglomeration. Loading can accomplish with our automated drum loading and discharging system. Controls including variable frequency drive and PLC can be supplied in NEMA-4X or NEMA-7&9 explosion-proof design. Available sizes range from 0.1 to 500 cubic feet working capacity.

www.pauloabbe.com

Processing and Separation Equipment & Systems

Founded in 1963, Pope Scientific, Inc. has established itself as an international leader in process equipment ranging from laboratory to pilot plant to production scale. At the heart of Pope's business is a focus on its customers' applications and requirements, and accommodating these with design, manufacture and testing of quality equipment to meet users' preferences and budgets. Industries served include pharma, foods, flavors, oils, biomedical, polymers, lubricants, electronics, specialty chemicals, etc.

Pope's Distillation equipment and toll processing services are highly regarded world-wide. Wiped-film short path molecular distillation and evaporation systems for heat-sensitive materials is a specialty in which Pope has guided clients from concept to testing, piloting and commercialization. Fractional column stills are also offered and the combination; the combination of these two still types as Hybrid Still systems is a solution to difficult separations.

Pope's pressurizable stainless steel Vessel Systems are likewise respected world-wide and include containers mixers, batch and continuous mode reactors, nutsche filer-dryers, and completely turnkey, automated, skid mounted custom processing systems. Pharmaceutical finishes, ASME and CE certifications available.

Being application focused and solution driven requires highly qualified technical staff and this is what you will immediately encounter when you contact Pope! **www.popeinc.com**

Economic Indicators

2020 2021 2022

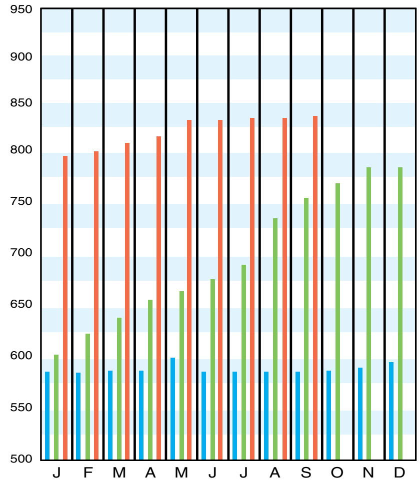
Download the CEPCI two weeks sooner at www.chemengonline.com/pci

CHEMICAL ENGINEERING PLANT COST INDEX (CEPCI)

(1957–59 = 100)	Sept. '22 Prelim.	Aug. '22 Final	Sept. '21 Final
CE Index	821.1	824.5	754.0
Equipment	1041.5	1046.7	946.5
Heat exchangers & tanks	872.3	879.5	810.6
Process machinery	1047.7	1054.5	958.5
Pipe, valves & fittings	1476.1	1480.9	1330.9
Process instruments	556.7	556.8	551.3
Pumps & compressors	1312.1	1305.3	1180.5
Electrical equipment	785.0	775.3	639.3
Structural supports & misc.	1166.6	1185.0	1038.9
Construction labor	362.0	358.9	348.4
Buildings	813.0	825.8	771.9
Engineering & supervision	311.8	311.6	311.1

Annual Index:
2014 = 576.1
2015 = 556.8
2016 = 541.7
2017 = 567.5
2018 = 603.1
2019 = 607.5
2020 = 596.2
2021 = 708.8

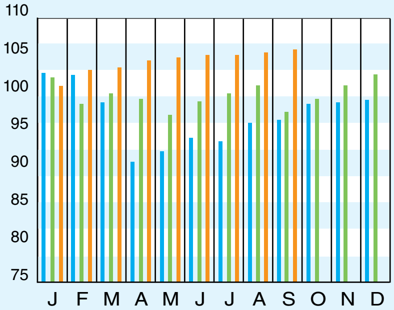
Starting in April 2007, several data series for labor and compressors were converted to accommodate series IDs discontinued by the U.S. Bureau of Labor Statistics (BLS). Starting in March 2018, the data series for chemical industry special machinery was replaced because the series was discontinued by BLS (see *Chem. Eng.*, April 2018, p. 76–77.)



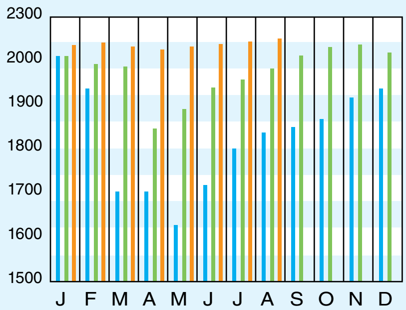
CURRENT BUSINESS INDICATORS

	LATEST		PREVIOUS				YEAR AGO	
CPI output index (2017 = 100)	Sept.'22	= 102.5	Aug. '22	= 102.3	Jul. '22	= 101.8	Sept. '21	= 98.6
CPI value of output, $ billions	Aug. '22	= 2,173.9	Jul. '22	= 2,169.9	Jun. '22	= 2,239.1	Aug. '21	= 1,835.6
CPI operating rate, %	Sept.'22	= 82.8	Aug. '22	= 82.7	Jul. '22	= 82.4	Sept. '21	= 80.1
Producer prices, industrial chemicals (1982 = 100)	Sept.'22	= 359.4	Aug. '22	= 364.1	Jul. '22	= 386.7	Sept. '21	= 327.5
Industrial Production in Manufacturing (2017 =100)*	Sept.'22	= 102.8	Aug. '22	= 102.3	Jul. '22	= 102.0	Sept. '21	= 98.2
Hourly earnings index, chemical & allied products (1992 = 100)	Sept.'22	= 204.2	Aug. '22	= 200.1	Jul. '22	= 199.8	Sept. '21	= 197.5
Productivity index, chemicals & allied products (1992 = 100)	Sept.'22	= 92.7	Aug. '22	= 93.6	Jul. '22	= 92.6	Sept. '21	= 94.4

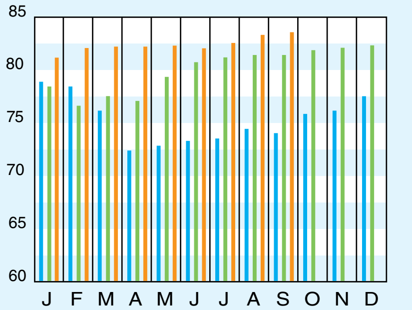
CPI OUTPUT INDEX (2017 = 100)†



CPI OUTPUT VALUE ($ BILLIONS)



CPI OPERATING RATE (%)



*Due to discontinuance, the Index of Industrial Activity has been replaced by the Industrial Production in Manufacturing index from the U.S. Federal Reserve Board.
†For the current month's CPI output index values, the base year was changed from 2012 to 2017
Current business indicators provided by Global Insight, Inc., Lexington, Mass.

CURRENT TRENDS

The preliminary value for the *CE* Plant Cost Index (CEPCI; top) for September 2022 (most recent available) fell for the third consecutive month, following a long string of increases between November 2020 and June 2022. For the September preliminary data, decreases in the Equipment and Buildings subindices offset small increases in the Construction Labor and Engineering & Supervision subindices to bring the overall CEPCI lower for the month. The current CEPCI value now sits at 8.9% higher than the corresponding value from September of last year. Meanwhile, the Current Business Indicators (middle) show small increases in the CPI output index and the CPI operating rate for September 2022.